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The impact of shared mobility services – carsharing - on the public transportation funding

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ABSTRACT

The new emerging means of mobility due to the transformative and revolutionary digital era and the transitioning towards a Mobility as a Service paradigm respond to diverse needs across the globe such as the fight against climate change, traffic congestion and travel time losses. These challenges are some of the drivers that shared economy into mobility is disrupting not only the understanding of mobility and commuters' behaviour, but also financial strategies in public transportation. Today, carsharing operation raised among 1,100 cities worldwide, in 26 countries and on 5 continents[1], what denotes a substantial presence whose effects are open to be object of further research.

This master thesis is based on quantitative as well as qualitative analysis to gain in-depth perspective of the effects of carsharing implementation on transportation' behavioural shift and on the variation of financial gap deficit inherent of public transportation.

The author provides a motivation analysis that puts forward the problematic related to these disruptive services, and it pursues to answer some questions about the future of mobility and how public funding will be subsidized to a major or minor extent due to carsharing advantages.

KEY WORDS: Carsharing, shared, mobility, service, financial, commuters, public, private, partnership, modal shift, Downs-Thomson Paradox, funding, investment, subsidy.

WORD COUNT: 28,281 words

[1] Navigant Research (www. navigantresearch.com/research/carsharing-programs).

EXECUTIVE SUMMARY

This master thesis proposes several questions about the impact of the implementation of carsharing services on public transportation in financial terms, focusing on three main aspects; the financial theoretical modal, transport modal choice analysis and qualitative analysis for several real case studies across the globe.

As it is necessary to contextualize the socio-political framework and the emerging trends of shared mobility, this maters thesis starts up with an introduction of Mobility as a Service paradigm and the rising trends of carsharing services. Following the principal aim of the master thesis, it delves into transport financial models as well as develops an algebraic financial model that expresses how does public transportation shift because of other mobility' alternatives such as carsharing. As it could not be different, a transport modal shift analysis has been detailed to further understand the faithful carsharing membership patterns, but also to analyse their potential attractors in long term. At the same time, the project perceives a practical point of view in Calgary, Vancouver, Ile de France urban and interurban areas, as well as the whole country; France, and furthermore a holistic and realistic approach has been taken into consideration while analysing the impacts from the use of carsharing. Doing so, it can have a big image of the whole behavioural shift and variances in demand shares in virtue of new shared mobility services. Not to mention, understanding the maturity model and the differences between cities compared to distinctive externalities also provides a future vision of the changeable mobility we are living and how the ecosystem should embrace each disruption to build an entire Mobility-as-Service system

To better perceive carsharing' impact, the master thesis has studied real cases through which commuters' disparate demand behaviours among all transport alternatives as a result of introducing car share, and how does public transportation' demand alteration also shift the public subsidies required to keep running an appropriate level of service in cities.

The collection of pre-established information and the experience of the author in Mobility as a Service and Smart Cities consultancy have supported the respond to all questions, contributing to the accomplishment of project research. Some of the reasons that encourage this research to study the effect of carsharing on public transportation' funding are the digital movement that is permeating everything plus the potential

momentum to improve commuters' welfare as a result of a new understanding of mobility as a service and not as property asset anymore.

Mobility as a service means more than a new technology to better embrace transportation system, it means a change of paradigm in the way commuters are getting around, reason that leads the author of research to be interested in learning about further effects and unstudied impacts due to carsharing.

MaaS stands for Mobility as a service and is an integrated form of transport, combining options from different transport providers into a single mobile service, removing the hassle of planning and one-off payments[2]. According to The European Mobility as a Service Alliance, the key concept behind MaaS is to put the users at the core of transport services, offering them tailor made mobility solutions based on their individual needs. In other words, future mobility includes accessibility, flexibility and intermodality from all ranges of transportation. At the same time, the master thesis search for an alignment to the United Nations Sustainable Development Goals (SDGs).

Moving towards a society in which mobility services require distinctive companies, industries and municipalities involvement, this mater thesis also studies the increase of collaboration and involvement of stakeholders in innovation ecosystem in transportation as a result of shared mobility. Furthermore, another question open to discussion throughout this master thesis is the induction of collaboration and interoperability of stakeholders in Mobility as a service business model as a result of shared mobility rising trends.

Therefore, these new means of mobility mark a change between the single-occupancy private vehicle use and the public-private collaborative services enhancing the interoperability and coordination between all stakeholders in mobility' ecosystem as well as establishing a common goal even though each one had an individual interest in the traditional model, for which reason Mobility as a Service and carsharing increase its efficiency results and the effectiveness of the travel experience.

[2] MaaS Global, https://maas.global/maas-as-a-concept/

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LIST OF ABBREVIATIONS

B2C:	Business to consumer
EoD:	Economies of Density
EoO:	Economies of Operations
EoS:	Economies of Scale
e-TEN:	Trans-European Network in telecommunications
EU:	European Union
ICT:	Information and Communication Technology
IdF	Ile de France
GHG	Greenhouse Gas Emissions
LoS:	Level of Service
MaaS:	Mobility as a Service
MTR:	The Mass Transit Railway Corporation
P2P:	Peer-to-peer
PPP:	Public Private Partnership
RACC:	Reial Automòbil Club de Catalunya
SDGs:	Sustainable Development Goals
SETA:	Single European Transport Area
SMC:	Social Marginal Costs
TEN-E:	Trans-European Network in energy
TEN-T:	Trans-European Network in transport
VfM:	Value of Money
VfP:	Value of People

CONTENTS

A. MOTIVATION

The globe is becoming increasingly urban rather than rural, and it is further foreseen to grow up to 66% and 34% respectively in 2050[3]. Moreover, the number of daily travellers and goods mobility are so demanding that we are living a changeable and revolutionary age when mobility and transport are being transformed. Plainly, population growth as well as the enormous migration to urban areas are fundamental triggers of reshaping future of mobility.

The continuous movement of urbanites in metropolitan areas, the increasing and dangerous effects of climate change and the unnecessary and disproportioned occupied space due to private vehicles are some of the factors why transportation planning and the understanding of mobility are globally changing. Not to mention that the optimization of value of time and money for commuters are being centralized, even more with the pass of the years by delivering a more customized and personalized pricing management together with accessibility to users.

Mobility as a Service provides flexible and ubiquitous alternatives, such as carsharing, which meet transportation needs across the globe. Innovative modes of transport in the market and a widespread tendency to extend mobility alternatives have a clear impact on commuters' decision variables and priorities. Furthermore, the transition of mobility business model goes hand in hand with a change of urbanites' behaviour, reason why this report will analyse transportation modal shift motivated by carsharing offering in order to gain more in-depth perspective in transportation future investment policies.

Today, carsharing operation raised among 1,100 cities worldwide, in 26 countries and on 5 continents[4] and it currently encompasses 1,788,000 members sharing over 43,550 vehicles[5], what raises the question of whether these services effect on other mobility alternatives survival such as public transportation. If so, how other technological and innovative demands such as integrated multimodality impacts on their usage and hence its economy.

[3] UN Department of Economic and Social Affairs, OECD/ITF, Arthur D. Little

[4] Navigant Research (www. navigantresearch.com/research/carsharing-programs).

[5] The University of California, Berkeley's Transportation Sustainability Research Center's (TSRC) survey (October 2012). Shaheen, S., Cohen, A. 2012, (tsrc.berkeley.edu/node/701).

Carsharing' value proposition shows that in French market the 25% of commuters take carsharing services regularly or occasionally. Indeed, earlier ages from 18-25 the portion of carsharing use attained 40%[6], what remarkably represents carsharing customer profiles. With this aim in mind, this report will look into the change of mindset that increasingly drives citizens to adopt transportation modes in accordance with efficiency and seamless, but not with assets' acquisition.

Worldwide, congestion is one of the main challenges in future of mobility as it causes many occurrences, for instance, the cost of extra time and fuel, reaching an annual cost of $100 billion[7]. These barriers and challenges are some of the determinants that contribute to shift behavioural mobility patterns in favour of carsharing services.

Raising growth in shared mobility services around the world, successive petroleum industry crises, restrictive automobile regulations in urban areas and environmental strategies are other drivers that encouraged this report to explore mobility' trends, the level of acceptance of carsharing' modes of mobility as well as their effects on society in financial terms.

In deep, digital era and the increasing number of mobility alternatives within Mobility as a Service' paradigm bring many low-cost improvements and add capacity in massive corridors, reasons why this paradigm diversifies the development patterns, provides multiple choices and thus, it changes the usage patterns. All these effects not only impact on commuters' behaviour, it also diversifies land use patterns or redevelopment solutions like public transportation service' usage. In other words, if public transportation service had been eliminated in continuous changeable land patterns, travellers could have experienced an increase in their hours of delay in 796 million as it occurs among 439 urban areas in the U.S. Moreover, the removal of public transportation would also be a root cause of an additional consumption of 303 million gallons of fuel, and thus, its presence and current usage save $16,811 million. [8]

Hence, this report asks itself about the economic effects of operating costs as well as how would funding and investment policies in public transportation change as a result of more sustainable, flexible and user-based emerging services just as carsharing. Still, public transportation does not cover the total operating costs because of revenues derived from ticket-sales. While Hong Kong transport model has reached a 185 percent

[6] BlaBlaCar, les secrets de la licorne (I). Etude de cas préparée par G Dang Nguyen pour le MOOC Economie collaborative Telecom Bretagne, Institut Mines Telecoms.
7 David Schrank, Tim Lomax, and Bill Eisele, "2011 Urban Mobility Report," Texas Transportation Institute, September 2011.
[8] David Schrank, Tim Lomax, and Bill Eisele, "2011 Urban Mobility Report," Texas Transportation Institute, September 2011.

of farebox recovery rate, other cities figure out an under-investment deficit to keep transport services running. Does carsharing introduction impact on public costs subsidised into public transportation? This answer will be delved into this report

All in all, multimodal integration is one of the catalyst of Mobility as a Service, and also a variable that puts forward a distinctive behavioural shift to widespread use of other sustainable transport modes.

B. INTRODUCTION

The new way of understanding mobility - Mobility as a Service paradigm -provides several thoughts open to debate; such as the transport modal shift, user patterns and the economic effects on the whole transport system. Shared mobility services are not completely established through major cities around the world as they drive new political, financial and methodological ways of working pending to explore in many countries. Additionally, MaaS and so shared mobility mean an integration of distinct transport modes which poses the question about new partnership' models between transport operators, automobile industry and public administration.

In other words, this report aims to study how does shared mobility become rising component of Mobility as a Service' paradigm, and, furthermore, the Public Private Partnership (PPP) collaborative models. Moreover, this report aims to analyse the effect of this rising trend - shared mobility - on transport modal shift and how the new user patterns modify the financing models in public transportation. These issues will be analysed according to several real case studies and through before-after analysis[9] of shared mobility existence in cities. Besides, this report also will include a Mobility as a Service expertise point of view, which will enrich the qualitative analysis about the challenges of the future mobility.

All told, this report asks itself about the existing issue and delimitates the scope of the problem. To do so, it places a several questions aimed to be answered and therefore formulates the objectives of the project listed below:

B.1. Questions

- What is the impact of the implementation of shared mobility services on public transportation investment?
- How does shared mobility services impact on transport modal shift?
- Which are the main user mobility patterns due to shared mobility models?

[9] Before-after analysis is a study that compares the situation between the before AS IS scenario and the TO BE scenarios between shared mobility services in the city

- How does intermodality between shared mobility services and public transport benefit public transportation usage?
- Which conclusions do shared mobility maturity model diverge between different cities?
- How can the inter-collaboration and involvement of PPP improve MaaS mobility models?

B.2. Objectives

- To determine the economic consequences of public transportation as a result of shared mobility services availability
- To analyse the transport modal shift motivated by new shared mobility models
- To identify the reasons and user travel experience that point out the rising use of shared mobility services
- To study how the intermodality between shared mobility and public transport improves the whole transport system of the city
- To compare shared mobility maturity models between different cities
- To reflect upon economic, collaborating and political challenges presented by future urban mobility models of MaaS

B.3. Methodology of research

The methods and principles seen through the research project are based on financial theoretical model development and empirical analysis. This study will develop a financial theoretical model of how does transport modal shift impact on the coverage of public transportation operating costs and which will further be particularized for each of the transport modal shift analysis at a later stage. Therefore, this study also will consider several shared mobility real case studies, which point out the consequences and real impacts in terms of mobility usage and investment indicators.

This real data gives information to describe mobility users' behaviours and reflect upon several challenges that Mobility as a Service foresees. The mobility expertise point of view and some theoretical analysis will justify and so substantialize the economic effects of these shared economy to public transportation.

This study will gain in-depth perspective by evaluating several shared mobility use cases and seeing the effect that this kind of services has inducted in terms of transport modal choice.

The main objective of this master thesis is to analyse the impact of the implementation of shared mobility on public transportation investment. Additionally, it will delve into the improvement and competitiveness of the whole transport system by means of building an intermodal and integrated system. It necessarily involves an analysis focused on the economic impact and the Public and Private Partnership model involved in MaaS.

B.3.1. Structure

This master thesis proposes several questions about the economic impact of the implementation of shared mobility services on public transportation investment, and hence the structure of the report is based on the following sections:

State of the Art, it outlines the disruption of transportation industry and the increase of shared mobility in many cities around the world. This section also deepens our knowledge in PPP model rising adoption due to shared mobility. Additionally, it analyses some of the political and social frameworks at a starting point of these future urban mobility models and, hence, it also points out the way forward.

Financial theoretical model, it defines macroeconomics parameters and models that define social, transport and external generalized costs that would be altered because of vehicle car ridership. Plus, it relies on different transport economical models in order to gain-in depth perspective and further understand economical impacts at the time of behavioural shift in mobility.

Transport Modal Shift Analysis, it presents the transport modal shift by virtue of these new shared mobility services in order to analyse financial effects on public transportation on lately section of this study. Moreover, transport modal shift analysis gains in-depth perspective of commuters' patterns and decision-making variables in pursuance of understanding the change of transport usage' patterns.

Financial effects on public transportation, it relies on the financial theoretical model designed on the previous stages as this section applies it on the particularities of each

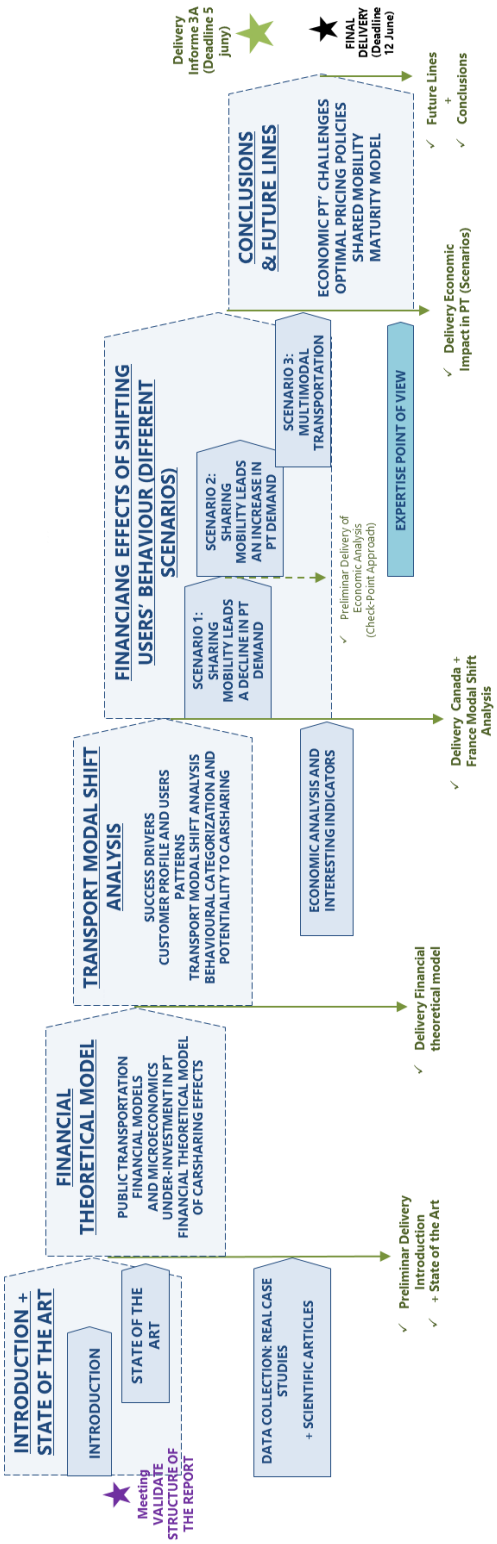
transport modal use cases studied. In other words, this section analyses different scenarios of carsharing services from different countries, mobility patterns, land use and socio-political frameworks; first independent to public transportation and second complementary to public transportation. This distinction and its comparison will allow this study to reflect upon the convenience of integrated multimodal transportation induction and the improvement of users' quality of travelling experience.

Conclusions, are obtained from the results and acquired knowledge during the whole study. It reflects the outcomes of the performed study.

Future lines, it proposes and encourages the study to further investigate other issues open to debate related to the changeable effects of shared mobility on public transport investment. In particular, how does shared mobility matured model among cities affect to the aim of study.

B.3.2. Workplan

Figure 1 Methodology of reserach: Structure and workplan



Source 1 Author's own

C. STATE OF THE ART

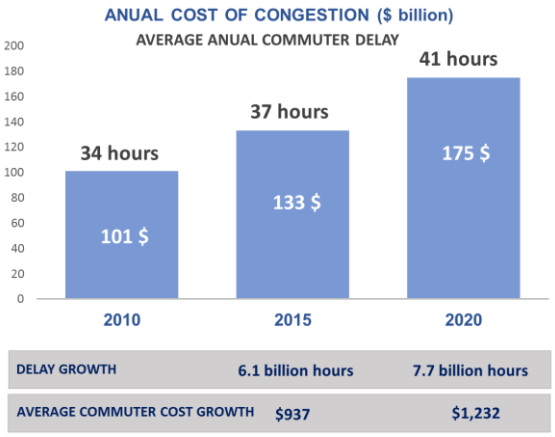
C.1. Shape of tomorrow's mobility

Nowadays we are living in a world where the migration around cities is enormously increasing, and thus, the growth of cities and its inhabitants tend to grow over time. In particular, Spanish urban areas experienced an average growth by 17.5% between 220 and 2010, and by 18.1% the earlier decade.[10] Furthermore, urbanisation and rising population growth are some of the main triggers that are reshaping the future of mobility.

The continuous population growth at urban areas and their evolving patterns of land use contribute to the fact that transportation system imposes huge costs not only to commuters but on society as a whole. According to RACC[11], the congestion to access to Barcelona grew by 28% from 2014 to 2015 due to vigorous economic recovery, and bottlenecks translate into a total of 683 annual cost per commuter. Likewise, the amount of time lost in transportation infrastructure due to congestions is excessive.

These effects have clear economic impacts, but also have environmental and social externalities that should be considered in order to address the problem.

Figure 2 Annual cost of congestion in United States



Source 2 Authors' Elaboration. Data: Urban Mobility Report September 2011, Texas Transportation Institute

[10] The growth of cities Gilles Duranton of University of Pennsylvania and CEPR Diego Puga of CEMFI and CEPR

[11] Reial Automòbil Club de Catalunya

The downward trend in car ownership in cities is another driver that makes it necessary to adopt new modes of mobility. This decreasing is even more pronounced in mega-cities, for instance, cities such as Tokyo, New York and London foresee a diminishing of the number of cars per 1000 habitants by 353 to 340, 230 to 220 and 400 to 340 respectively between 2009 and 2025[12]. That is to say, other trends such as vehicle non-ownership and sharing trends are significantly getting weight in Europe and North America.

C.1.1. Transportation digital age

Sum to the fact that we are in a changeable and transformative age where industry revolution 4.0 and data layer have gained momentum, the transportation system has the opportunity to rethink the behaviour of urbanites and evaluate the property enticements that would invite an improvement of this reality.

Smart Cities are more than technological devices around metropolitan areas, they aim to improve quality of life by means of data management. Furthermore, in this case, Smart Cities and new urban mobility planning enhance the development of connectivity, accessibility as well as the fight against environmental issues.

Not to mention that the arrival of digital age is allowing transport systems to gather information about the modal shift patterns accessibly and easily through smart-phones and connected devices. This, to whom it might be reluctant to deliver their daily data, this information is finally used in their beneficial although population could not directly perceive it. The revolutionary technological industry that is continuously moving useful data information means an opportunity to transport operators, municipalities and other stakeholders to favour customer experience as well as to establish air quality restrictions

[12] Frost and Sullivan (2014) Strategic Insight of the Global Carsharing Market. Report #ND90-18, June 2014.

in order to diminish pollution and the environmental footprint for the sake of society welfare.

However, as we are encountering enormous amounts of data, those days the debate is open against the democratization and sharing of this gathered information. Further on, this report will analyse how to address this challenge by means of Mobility as a Service paradigm, integrating and connecting transportation modes and services through innovative technologies.

C.2. Mobility as a Service' paradigm

In the 21th century cities around the world are adopting the digital infrastructure and reshaping the ways that urbanites get around the city in order to become sustainable, more liveable and smarter. Because each urban planning, population density, household income, public investment, the state of roads and public-private partnership openness and user behaviours in cities is unique, the transition to integrated mobility will also play out distinctly.

One of the gurus of Mobility as a Service paradigm, Sampo Hietanen[13], asked himself how to conform mobility and accessibility among cities as the new the Netflix' business model. In other words, those days where climate change and the associated policies are such relevant that he figured out the paradigm of mobility in which users are the core of transportation system and through which owning a vehicle is losing weight.

Different factors are fuelling the new model. Digitalisation, climate change polices including sustainable new modes of mobility and the increasing reticence to own vehicles are some of the factors that are disrupting the traditional means of transportation.

Furthermore, Mobility as a Service is a new understanding of mobility through which transport services provide flexible solutions. MaaS is an integrated form of transport, combining options from different transport providers into a single mobile service, removing the hassle of planning and one-off payments. [14] According to The European Mobility as a Service Alliance, the key concept behind MaaS is to put the users at the

[13] CEO and Founder of MaaS Global, the Finnish startup behind Whim, and the father of the MaaS concept.
[14] MaaS Global, https://maas.global/maas-as-a-concept/

core of transport services, offering them tailor made mobility solutions based on their individual needs. In other words, future mobility includes accessibility, flexibility and intermodality from all ranges of transportation.

C.3. Shared mobility

Urban passengers and goods mobility demands are globally foreseen to increase 1.9-fold and 3.0-fold respectively from 2010 to 2050. Besides, the evolution of congestion level has experienced a significant increase around the world by 2.6% from 2008 to 2016 - 2.5% in North America and 1.1% in Europe, what lead mobility to adopt shared economies that are reshaping mobility, and hence, are changing passengers' trends and behaviours.

The concept of shared mobility represents the non-ownership of vehicles as well as a collaborative consumption and economy. It is a ubiquitous model of transport that puts forward an emerge on-demand mobility system, through which commuters understand their mobility as a popular right used interchangeably, instead as a private and individual asset.

Shared mobility has significantly been embraced over the last years around the globe. Carsharing has grown 12-fold in the last decade and is estimated to surpass membership over 23 million globally by 2024. Public bike sharing has grown 100-fold since 2004 in more than 50 countries.[15]

After all, these new means of mobility go further as they underline and induce interaction and collaboration with new actors. This new model of mobility requires the exchange of information in order to build an online platform that provides flexible services widely associate to socio-economic models as they are a current reality of cities and daily form of mobility for urbanites.

Worldwide, shared mobility can be distinguished between different forms; bike sharing, carsharing, carpooling, ridesharing and ride-splitting. Particularly, carsharing has been

[15] JOHN E. MICHEL 2018, Mass Transit. Mobility-as-a-Service: Enabling the Transformation of Transportation through Digitalization

the pioneer mode of sharing economy, given it ushered in a new way of understanding and access to the private vehicle in the 20th century.

Nevertheless, although there are different kind of shared mobility operators, all of them converge with the advent of the shared economy and digital age. These services have no sense without a technological basis through which peer-to-peer services and commuters' transactions are managed. In other words, shared mobility services go hand in hand with information technology layer.

Other considerations that should be highlighted among these mobility services are the free-floating carsharing, more flexible and pervasive, and the station-based bike sharing system.

C.3.1. The United Nations' Sustainable Development Goals achievement

These future models of urban mobility provide interconnectivity to boost economic trade and development, improving efficient travel and reducing climate change impact. It is worth mentioning that shared mobility is a step away in the way to achieve The United Nations' Sustainable Development Goals (SDGs).

Figure 3 How SDGs are addressed with carsharing

Source 3 Authors' own

SDG 3: Good Health and Well-being: As urban density continues to grow, the availability of shared mobility in cities led commuters to change of their patterns and to increase their use of non-motorized vehicles, reason why citizens' well-being is significantly achieved by cause of shared mobility services. Besides, carsharing customer experience and membership growth show up an improvement of level of service for commuters and their welfare.

SDG 8: Decent work and Economic growth: Further on, transportation and shared economies are important elements in encouraging economic development. All involved industries in carsharing services have been experimenting increases of revenues of 650 million euros per year around the globe[16] and these new models are also being productive of employment. Additionally, individual economic growth is prominent as they allow to avoid fixed costs and inefficiencies by automobile ownership. In like manner, personal automobiles remain idle on average 95% of the time and carsharing provide alternatives and a decline of cost savings (Sonuparlak, 2011).

SDG 9: Industry, Innovation and Infrastructure: Digitalization and innovation are fundamental layers that make possible carsharing implementation in cities, so they definitely build resilient infrastructure focused on affordable and equitable accessibility and connectivity.

SDG 10: Reduced Inequalities: It is tackled by means of shared mobility as these new models of mobility offer inexpensive access to electric vehicles for a broad segment of the urban population that do not own car.

SDG 11: Sustainable Cities and Communities: Shared mobility helps fight air pollution in cities and also it allows to reduce public expenditure on upgrading vehicle-focused road infrastructure due to the decrease of vehicle ownership. Furthermore, carsharing services as are pioneer in shared economies worldwide they seek for citizen settlements inclusive as well as improve interconnectedness and cross-border traffic between cities.

SDG 13: Climate Action: These services avoid air pollution, and hence, they considerably help to prevent climate change and to concern healthy habitudes. Theremore, carsharing companies are emerging to zero-emission automobiles so they are indirectly strengthening citizens commitment to sustainable mobility.

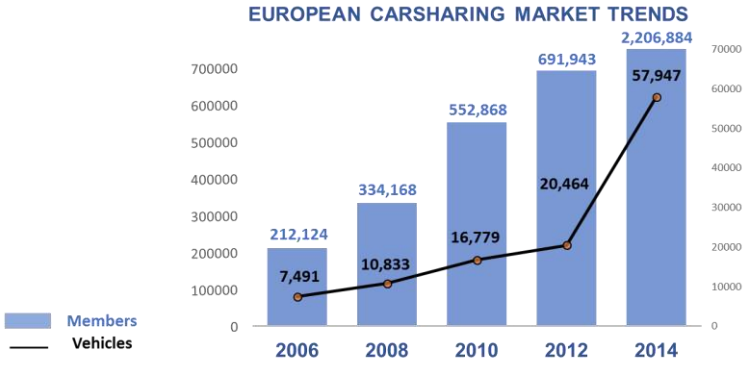
[16] Julien Bert, Brian Collie, Marco Gerrits, and Gang Xu. What's Ahead for Car Sharing? The New Mobility and Its Impact on Vehicle Sales. 2016

SDG 17: Partnerships for the Goals: Shared mobility requires both public and private relationships to build experience and carsharing resourcing in cities. Today, the wide range of mobility alternatives revitalize partnerships and win-win alliances to promote effective, equitable and sustainable shared mobility services.

C.3.2. How shared mobility becomes a rising component of MaaS

In the framework of MaaS, there are different factors that lead shared mobility to become a rising trend all around the countries. First, negative environment effects of transportation industry and air pollution impact in cities have enforced this trend. Second, economic crisis is shaping low-cost services generated on demand. Third, urbanites get around are increasingly aware of the convenience of accessibility rather than vehicle' ownership. Fourth, data layer and Information and Communication Technology (ICT) allow for seamless communication. All these factors together have accelerated the rising trend of shared mobility.

Figure 4 European Carsharing Market Trends



MEMBERSHIP GROWTH RATE		26%	29%	12%	79%
		20%	24%	10%	68%
MEMBERSHIP GROWTH RATE	28.3	30.8	32.9	33.8	38.1

Source 4 Susan Shaheen and Adam Cohen, Innovative mobility carsharing outlook: Carsharing market

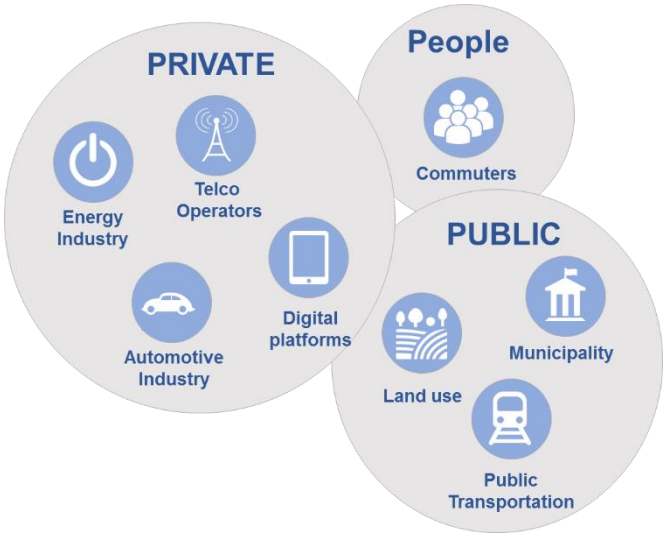
The exhibit below represents the increasing tendency of carsharing market in Europe, from 2006 to 2014 the membership growth rate reached 79% growing their number of members up to 2,206,884. Moreover, vehicles in 2014 was 7.7-fold the last eight years.

C.4. Shared mobility involves Public Private Partnership

Mobility as a Service and so shared mobility services present a new reality to transport stakeholders management, trigging new collaboration models between different actors involved among urban mobility.

As shared mobility means an integration of transport services into a single mobility service accessible on demand, it requires an emerge to privatisation and new regulatory approaches.

Figure 5 People first Public Private Partnership actors



Source 5 Authors' own

Furthermore, it requests the attention from both public and private sectors to ensure consistency in cities around the world. Hence, shared mobility concludes a transition to Public-Private Partnerships (PPPs) models as it includes private actors such as automobile industry but also municipalities and authorities who deal with policy and regulation transportation inclusion of the system.

For instance, the perception of private automobile with the implementation of carsharing is completely revolutionised. Thus, shared economies among mobility emerge to new public-private partnerships.

If managed well, governments tackle development needs of urban grid by using partnerships for sustainable development of transportation networks in territory. In that sense, shared mobility puts commuters at the core of business model improving their travel and making them more efficient. Consequently, shared mobility would bet for a more-advanced collaborative model; People First Public Partnerships (PfPPP), through which people is the main priority and beneficiary.

As PfPPP models prioritize customer preferences among shared mobility services, those are based on the following main values: reliability, safety, comfort, equity, transparency and community. Not to mention that these models are further focused on availability, replicability, equity, efficiency, sustainability and effectiveness.

Although these collaboration models are clear in MaaS systems, this report will further analyse the induction of alliances between public transportation and shared mobility services in order to step towards ensuring urban transport system as a whole. In other words, shared mobility raises an issue about the interconnection with public transportation in order to engage the greatest benefit to the people the service aims serve. Hence, some parameters such as Value of Money (VfM) and Value of People (VfP) will be considered deeper at a later stage of this report.

C.5. Carsharing' presence in the globe

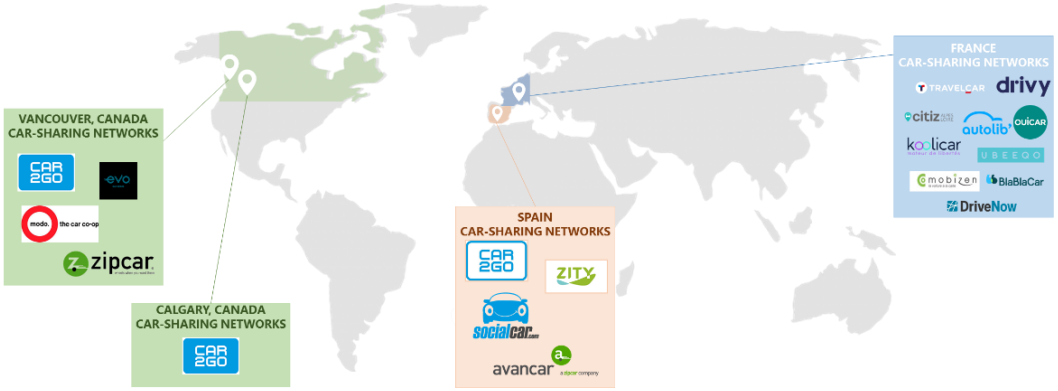
Carsharing is operating in 33 countries, five continents and approximately 1,531 cities with 5 million members sharing 104,000 vehicles in 2014[17]. In terms of membership, Europe remains in the leading position worldwide with 2.1 million users and also boasts the higher service per capita, and lately North America with 1.5 million. Moreover, Asia-Pacific, including Australia, China, Hong Kong, Japan, Malaysia, New Zealand, Singapore, South Korea, and Taiwan join 2.3 million carsharing users. [18] Although the leading position of membership was for Europe, it does not occupy the largest number of vehicles in the continent so that Asia-Pacific does with 33,000 vehicles. Europe holds

[17] Susan Shaheen (2016) Move Forward (https://www.move-forward.com/carsharing-trends-upward-worldwide/)

[18] Julien Bert, Brian Collie, Marco Gerrits, and Gang Xu. What's Ahead for Car Sharing? The New Mobility and Its Impact on Vehicle Sales. 2016

31,000 vehicles and North America 22,000, which indirectly concludes a further efficient use of the public space in Europe rather than in other areas worldwide.

Figure 6 Carsharing networks companies in Research Case Studies (Canada and France) as well as Spain



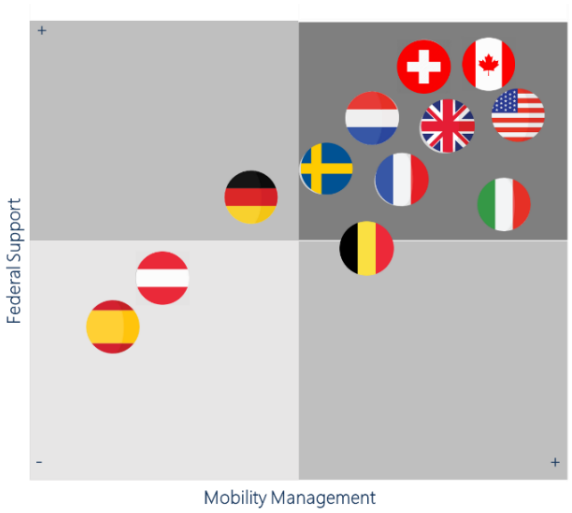
Source 6 Autor's own. Data: multiple sources

C.5.1. National frameworks in favour of carsharing

Each nation and continent has their political frameworks that conditionate the grade of acceptance and adaptability of carsharing services within their territories. Thus, balancing mobility management commitment versus federal support allow to contextualize the level of acceptance in carsharing' real cases further analysed on later stages of this study.

In this perspective, mobility management is understood as promotion of sustainable mobility, consciousness of climate change action, road pricing management and travel awareness on modality. On the other hand, federal support concept includes political frameworks such as national financial policies, parking, urban planning and land use strategies, toll management and incentives to subscribers, which dynamize and agile the inclusion of carsharing among the world, but also contribute to break with social reluctance.

Figure 7 Political support and Transport Management Balance



Source 7 Authors' own: Data: multiple sources

As balanced previously, the cases studies deeply analysed later: France and Canada occupy different positions. As a matter of fact, Spain is characterized by its social reticence and political barriers, France is well-balanced in terms of mobility management as well as federal support, although United States and Canada are even well-positioned.

C.5.2. Socio-political context in research case studies

I. Carsharing acceptance transition in Vancouver, Canada

Nowadays Vancouver is known as the capital of carsharing in North America as it reaches the largest ratio of carsharing vehicles per capita than any other city in the continent. Thus, the city has 3,000 cars available and a remarkable fleet size all across Canadian cities[19]. That is to say that Vancouver and its proactive political frameworks demonstrate evidence that car share is helping to address regional interests around land use, transportation planning, affordability and the environment.

[19] L.William-Ross, 2018, VANCOUCERCOURIER, Vancouver has embraced car-sharing more than any other North American city

Some regional policies and plans from local authorities put forward a clear inclination towards proactive regulations whom accompany carsharing into the region as well as its commitment to develop model bylaws that facilitate low carbon transportation choices, such as carsharing. [20]

In contrast to the following cities, Vancouver legacy of regional planning has been a trigger to provide carsharing as another transport choice that fosters economic growth, mobility and livability to residents.

I. Carsharing acceptance transition in Calgary, Canada

Otherwise, Calgary also holds favourable political regulations willing to implement carshare in the city, but reluctant to spread out their service among interurban areas. Nevertheless, there is no doubt that Calgary as Canadian city strengthen the promotion of carsharing usage as sustainable modes of transport by means of embracing disruptive forms of mobility into the scope of regulations.

However, social framework and the perception of those services from Calgarians also play a contributing role to carshare acceptance in the city. Its citizens exhibit a lack of understanding about the benefits of these new innovative services and most of them are likely to disagree their implementation due to the considerable difficult to find on-street parking in urban areas.

II. Carsharing acceptance transition in France – Ile de France

Oppositely, Paris incorporated shared mobility services such as Uber system, and the regulatory adaptability was quite easier than the following Spanish model; C.5.2.I, as they had a proactive approach to regulate this kind of future model of mobility. Furthermore, after they passed through several scrutiny procedures, the government decided to launch Uber service in France.

Nevertheless, since January 2016 authorities have detected some illicit economic charges in Uber usage because some drivers adopted taxis patterns waiting in the street

[20] The Metro Vancouver Car Share Study, November 2014

for new customers. Due to these complaints, Uber is currently obligated to return to their depot before starting a new customer service.

Otherwise, France is the European leader in peer-to-peer carsharing (e.g. BlaBlaCar). Car schemes such as Autolib are world-leading examples of the B2C model[21] and P2P platforms such as Drivy. Additionally, Autolib service steps forward after its highly popular Velib' bike sharing system converting Paris in a diverse-shared mobility model.

However, Paris is not pioneer in car sharing services, but it is the first to do with a fully electric fleet. This model is economically profitable, and urbanites appreciate the concept of not pollute the air.

I. Carsharing acceptance transition in Spain – Car2Go Madrid, Spain

Although some services of shared economy such as P2P accommodation rentals[22] are importantly present in Spain, shared mobility has encountered more barriers to be installed in this country. In other words, peer-to-peer transportation platforms have been subjected to regulatory pressure from local authorities. Even more, Spain has become the most restrictive member state to this new business model as it infuried market incumbents such as taxi drivers.

At the moment, carsharing has entered in advanced in the Spanish capital and currently there are different carsharing serving in this city. Although the Spanish authorities had shown reticence about Uber platform, Car2go has been welcomed successfully and rapidly by the Spanish urbanites turning the city into the highest rental rate among car2go's 26 city network. What's more, Madrid carsharing usage patterns in terms of number of trip per day and per vehicle and the trip length are considerably high.

In addition, car2go carsharing is an electric mobility service, what is translated into an enticement to change commuters' behaviour, and so to raise awareness among citizens of environmental case through more sustainable modes of transportation.

[21] B2C, the acronym for "business-to-consumer", is a business model based on transactions between a company, that sells products or services, and individual customers who are the end-users of these products. Source: Virtocommerce B2C model

[22] Peer-to-peer property rental (also known as person-to-person home rental) is the process whereby an existing house owner makes their house or an empty room available for others to rent for short periods of time as an alternative form of accommodation.

D. THEORITICAL FINANCIAL MODEL

D.1. Background

The future of interurban and urban public transportation will not only be affected by behavioral shift of users, it also will be disrupted concerning investment decision-making policies. Traditionally, public investment to transportation has been such wide to cover the construction of infrastructures and also because of government strategies to promote some transport modes beyond other alternatives. For these reasons, in this era when mobility is transitioning towards new paradigm with the emergence of further alternative modes, which additionally require new regulations and collaborative models, investment in public transportation growth, maintenance or modernization are some of the concerns open to reflect.

Therefore, the influence of public decisions and investment strategies are some factors that could change the current imbalanced costs of public transport producers in exploitation and which are object of study in this section of the master thesis.

As the nature of public transportation puts forward, operation costs of public transportation are not covered by means of income from ticketing and pricing taken to travel. In other words, public transportation holds an inherent economic deficit to assure their operation as well as an adequate level of service. Some of the primary suggestions to respond to that deficit gap in public transportation are to increase public transportation demand or to adopt more customized pricing strategies, nevertheless they remain an ongoing and open item for later consideration.

All in all, public transportation is globally considered as a public right, sustainable mode and potential asset to boost economic growth for regions, though it suffers economic losses in their exploitation accounts so that it requires subsidies and public funding. With this aim in mind, influencing an upward tendency in public transportation' pricing policy should be substantiated by rational and weighted reasons as it is identified as a public mode of mobility.

It makes sense, therefore, to note that deficit financial gap in public transportation among different cities around the world is completely disparate. In addition, performance rates

and government decision-making behave uniquely in each country, and hence, public costs are differently demanding according to the reality of each case. Nevertheless, it should be underlined that public transportation networks all across the world experience an uncovered financial gap from ticketing, exclusive of Hong Kong case where its public transportation exceptionally turned up to be profitable[23]. Not to mention, Hong Kong became a worldly reference in public transportation financial management as the city understood that transport networks are more than just a means of transportation – it is also essential to the well-being of a city's population and economy[24]. Impressively, their farebox recovery ratio[25] was 123.68%, the highest of the entirely world[26].

D.2. Introduction to transportation social costs

Carsharing and Mobility as a Service are triggering variances for the economy of transport' alternatives as each one presents distinctive flexibility and connectivity, and hence users' patterns shift imply cost variation. Nevertheless, these innovative transport modes also entail differences in their exploitation costs. As this report initially aimed to reflect on the financial impact of carsharing on public transportation, this section will devolve into global transportation costs in the direction to explore about the particularities of economy due to new mobility models.

Furthermore, financial analysis of transportation should consider associated resources costs by means of considering the range of transport alternatives available in the market as well as user costs through evaluating monetary value of them to move from point A to B.

Thus, the social cost that respond to specific level of service (LoS); in their transportation means to be the following, C_s;

$$C_s = C_p + C_u + C_E \quad (1)$$

[23] The Unique Genius of Hong Kong's Public Transportation System. The use of a clever financing system has enabled the territory to provide world-class service—without breaking the bank.
[24] The Unique Genius of Hong Kong's Public Transportation System. The use of a clever financing system has enabled the territory to provide world-class service—without breaking the bank.
[25] The farebox recovery rate, also called F_{rr} at the theoretical model of this report, determines the percentage of public transportation operating costs incurred integrally by users because of ticketing-sales (R.Riol and A.Obiols, 2012). The more the farebox recovery rate is, the less public costs would have to fund in public transportation.
[26] MTR Corporation, 2017, *2016 Annual Report – Notes to the Consolidated Accounts*.

where C_E are extern costs fall on other society agents, no necessarily being transport producers or users such as harmful environmental effects, C_p are transportation producers costs, and C_u are costs incurred by transport users.

Both carsharing and public transportation modes agree with the previous global cost expression, although each one would be determined and influenced by different parameters. Nevertheless, turning to the principle objective of this report, this section does not go through considering each computing cost for both alternatives, but delves into public transportation financing policies in the interest of this report to figure out the economic consequences due to carsharing.

With this in mind, this report reflects upon the impact of carsharing services towards operating expenses of public transportation due to demands fluctuation and hence marginal costs variance. Therefore, what does carsharing imply to public costs? Does shared mobility contribute to streamline subsidies and federal grants to pay existing expenses or inversely exacerbate them? Both answers are open to discuss with the internalization of both financial models.

In essence, and according to theoretical analysis reported previously, carsharing economic effects on public transportation suggests being studied by means of public transportation demand alteration, differences of pricing strategies or investment policies and transport distribution networks that provide greater LoS to commuters.

And even still, although carsharing introduction would shift users' behaviour and generate demand fluctuations, which will be further analysed at a later stage of this report, there would be fixed costs among operating expenses of public transportation that must remain covered anyway. For this reason, this chapter goes deeply to the expression of social costs mentioned before, with the aim to better understand its economic effects.

D.2.1. Transport producers' cost

Transport producers' costs arise from construction, operation and maintenance of transport infrastructure, $€_L$ ($\frac{€}{km \cdot h}$); that will provide the level of service needed according to travellers' demand and private car rate of use, but also those derived from acquisition

and operation of vehicles to move from different locations , $€_V$ $(\frac{€}{veh \cdot km})$; and those from fleet size $€_M$ $(\frac{€}{veh \cdot h})$. Nevertheless, transport producers' costs turn into arduous determination of accurate values as each transport mode and infrastructure requires many particularities, differentiating higher fixed costs between minor variable costs. Furthermore, transport is subject to economies of scale, (EoS); that makes even more difficult costs policies to cover total costs.

Additionally, the wide range of transport alternatives commonly has indivisibilities inherent because they imply discrete occupancy differences when there is a variance on transport demand. Thus, transport simultaneously presents economies of density, (EoD).

Therefore, transport providers' costs are affected by demand share variations. As carsharing emergence causes new mobility patterns, the financial terms of transport exploitation are shifted and object to be explored.

D.2.2. Users' costs

Both private and public transportation agree that the most important expenditure among user costs is associated to monetary value of time taken to move from origin to destination, $T\,(h)$; not only for the in-vehicle-travel time , $\frac{E}{v_c}(h)$; but also for walking access time, $A\,(h)$; and the waiting time and transfers time, $W\,(h)$. Moreover, vehicle occupancy during the rush hour generates congestion and huge amount of travel time losses that affects to users cost. To simplify costs analysis, the following expression defines the generalized costs that users must pay to commute from origin to destination:

$$€U = vt + \theta + p = C_u + p \tag{2}$$

Where all the monetary values of time taken during the travel is expressed as vt; (e.g., $T\,(h)$, $\frac{E}{v_c}(h)$, $A\,(h)$ and $W\,(h)$), the monetary value of other disutility elements associated to the trip or external costs incurred by other members of the society rarely included in user costs, θ; and p which represents the ticket-payment incurred by travellers.

Other external costs that are generated by other members of the society are rarely incurred by users. Nevertheless, their current tendency is to a be disbursed for whom generate them.

Many examples put forward the fact that the monetary value, which users should face, does not include the whole value of commuting; the commuter occasionally incurs the car ownership operating costs, whether their infrastructure choice has toll management or not. In addition, some circulation tax cover construction, maintenance, signaling and other involved costs in the equation, which originally do not seem envisioned.

As it will be analysed in a later stage of this master thesis, the value of p that the user pay for their trip should ideally represent the marginal cost of the performance of the transport service, nevertheless, in practice, it does not represent all of them.

D.2.3. External costs

There is, moreover, several associated costs to externalities that users do not directly pay for in their trip. Even though there are positive as well as negative externalities that should be considered, uniquely the negative are translated into an external cost.

Some of these externalities are particularized for each transport modal choice. Thus, the main externalities associated to costs are environmental harmful effects per trip such as air pollution, acoustic contamination, and congestion travel time losses.

That is to say, Mobility as a Service and carsharing are some disruptive services that provide convenience, environmental-friendly and other decisive variables for users that are altered adopting new means of mobility, and at the same time, changing associated externalities.

D.3. Microeconomy of public transportation

D.3.1. Initial notions

As it has been reported previously, transportation puts forward EoS, reason why transport producers' costs as well as users' costs pose the question about the effect of demand, offer and other externalities towards individual and global costs of the system. To delve into this statement, this report aims to gain knowledge about transportation microeconomics; which distinguish between total costs, C_T; average or unitary costs, C_{Av}[27]; and marginal costs, C_{Mg}[28] (G. de Rus, 2008).

Simultaneously, transportation system, and mainly among transport producers' costs, presents both fixed and variable costs. Those last variable costs are the susceptible to be shifted because of a minimum variance in the level of service in transportation.

In addition, the implementation of new modes of mobility changes users' perception and behaviour, but also improves pricing offers becoming more similar to social marginal costs so that it turns them into a more competitive mode rather than traditional alternatives. The introduction to private transport operators are increasingly revolutionizing social marginal cost rules as their introduction reveals new externalities.

D.3.2. Assumptions to the study

To gain in-depth knowledge to transport macroeconomics and understand the disruption of carsharing into public transportation investment policies, this report firstly set up some assumptions to the study:

(i) Given that public transportation has economies of scale, and hence the marginal costs result lower than average costs, what puts forward that public transit networks do not cover all the operational expenditures by means of ticketing

[27] Average or unitary costs is the ratio between the total cost of transportation system as a whole and the number of users

[28] Marginal costs in transportation is the amount of extra cost that one more vehicle or transport service compute to the global costs

pricing (Ardila-Gomez and Ortegon-Sánchez, 2016), apart from exceptional cities such as Hong Kong. In other words, public transportation networks require subsidies to cover the whole incurred costs.

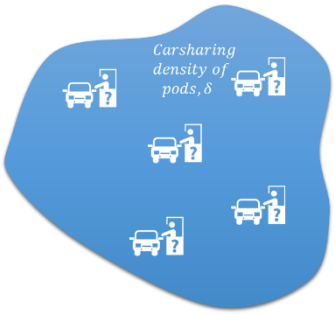
(ii) There is a decline of the average costs of transportation system with the extension of public transportation network (H. Mohring, 1972).

(iii) The optimal price for society is that in which case social marginal costs are equated with the willingness to pay (S. Maffi et al., 2010). In other words, social welfare in terms of transport pricing is maximized when price is set equal to social marginal cost (SMC). (A. Pigou, 1920)

D.3.3. Microeconomics effects in public demand variation

At the same time, this report proceeds to analyses Mohring Effect[29] and explore all the public transportation financial models to further understand the effect of recent modernizations of transportation as a whole.

Indeed, as long as public transportation network grows, average or unitary costs decline. This effect also supports the statement that affirms that public transportation holds economies of scale in public transportation. In other words, social marginal and average costs decline in the process of transport demand rise. This observation is a result of considering the economies of operation (EoO), which argues that in view that smaller transport infrastructures and occupancy turn up to have higher unitary costs, the magnitude of fixed costs is closely related to level of service (G. de Rus, 2012).



Leveraging the previous remark about the articulation between fixed costs magnitude and the level of service, this could be extrapolated to carsharing services in some way as their fleet size and amount of carsharing pods across cities reflect a notable change in its level of service. Nevertheless, carsharing services do not obtain a decline of unitary costs for users due to an increase in membership. These innovative services are based on pricing per use so that their exploitation costs do not behave similarly.

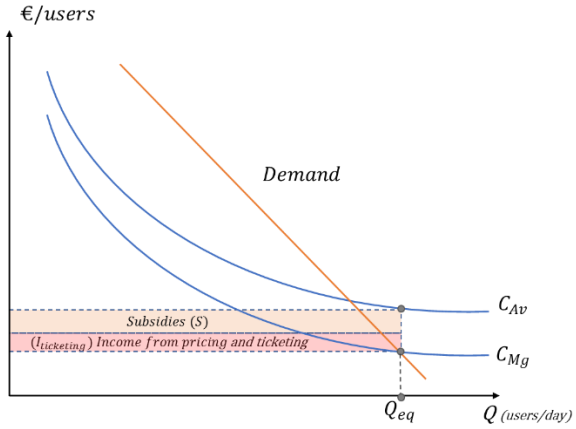
[29] The Mohring effect (H. Mohring et al., 1972) states that if frequency of public transit service increases with demand, then a rise in demand is translated in a decline of individual costs as their waiting times are optimized.

That is to say, the average or unitary costs are always higher than marginal costs (G. de Rus et al. 2003). For this reason, Figure 8 argues to the following expressions (1,2) in which users perceive a lower social marginal cost than the average cost of these means of transport.

$$\frac{dC_{av}}{dQ} < 0 \tag{3}$$

$$\frac{dC_{av}}{dQ} = \frac{C_{Mg} - C_{av}}{Q} \tag{4}$$

Figure 8 Mohring Effect: Income from ticketing and trade-off between offer and demand



Source 8 Elaboration: Mohring Effect, (Mohring, 1972)

In addition, the operational financial gap in public transportation that requires public contributions or subsidies to respond to optimal service for social transportation is described in the following expression;

$$Subsidies\ or\ deficit = \frac{C_{Av} - C_{Mg}}{Demand} \tag{5}$$

This report repetitively proved that the introduction of carsharing services causes a significant behavioral shift among users and hence to adopt new modes of mobility or even to embrace new multimodal alternatives compared to previous scenario, without shared mobility.

Although carsharing services affects to the demand on public transportation distinctively; depending on the city, the mindset of population and other parameters, in all cases they

modify the amount of deficit among public transportation. Thus, subsidies invested to the inherent deficit in public transportation would have been changed. In other words, for public transportation nature, deficit is commonly attached by pricing and ticketing policies or public investment, which in case of shared mobility' introduction, those would be also altered.

D.4. Subsiding model in public transportation

D.4.1. Under-investment in public transportation

It is common in most countries around the world that local authorities and municipality administrations generate a downward spiral of under-investment to assure the provision of transportation services as they are relationship human right and to ensure social equity for all citizens within their area[30]. In other words, the shape of transportation tariff and provisions for certain social categories generate necessary subsidies to cover the operational costs for public transit vehicles as well as its infrastructure.

According to microeconomics reported in the previous chapter and to the expression of subsidising of public transport; D.3, this section delves into the changeable subsidize share in regard of the respective transport demand shifting as a result of the implementation of carsharing as well as driven by the potential reduction of the need to use personal vehicles.

In efforts to ensure the adequate level of service and preserve the desired running of public transit, there is a subsidising requirement. Subsidization of public passenger transport is expressed by the following variables;

$$S + I_{ticketing} = O_{expenses} \tag{6}$$

Where,

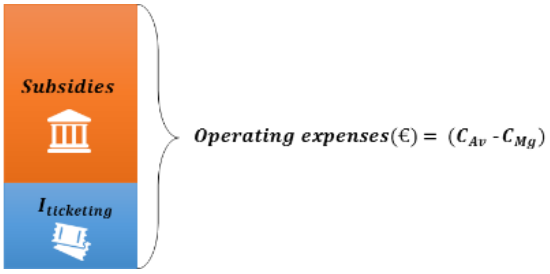
$O_{expenses}$; Required expenses to keep public transit operating

$I_{ticketing}$; Income derived from ticket-sales fare revenues

[30] R. Riol and A.Obiols, 2012, Materials CiP, *El futur immediat del transport públic*

S; subsidies or public funding to public transportation. In other words, it is the financing gap or deficit mentioned previously.

Figure 9 Operation costs of public transportation system: subsidies and income from ticketing



Source 9 Author's own

Figure 9 shows that although public transportation generates an income from ticket-sales, it does not respond to the total operating costs of collective transportation. For this reason, this system requires subsidies, government grants or supplementary taxes to keep public transportation running.

Farebox recovery rate, F_{rr} ; determines the percentage of public transportation operating costs incurred integrally by users because of ticketing-sales (R.Riol and A.Obiols, 2012). The more the farebox recovery rate is, the less public costs would have to fund in public transportation:

$$F_{rr:}\ Farebox\ recovery\ rate\ (\%) = \frac{Fare\ revenue\ (€)}{Operating\ expenses\ (€)} \qquad (7)$$

where, ideally, it would be higher than 100% and hence public transportation would obtain profit, what actually does not commonly happen. Besides, Spanish cities reached a coverage fare by 40-50% and German cities by 70-80%[31].

In substance, ticketing' monetary reuptake from travellers also depends on pricing policies and strategies of each city and region[32]. According to previous farebox recovery rate definition, an increase in fare revenues from users would be advantageous for a

[31] R. Riol and A.Obiols, 2012, Materials CiP, *El futur immediat del transport públic*
[32] G. de Rus, 2012, *Economía del Transporte*

decline of deficit in public transportation[33]. Nevertheless, revenues from ticket-sales uniquely goes hand in hand with a rise in public transportation' demand and/or its price.

Even though demand is slightly elastic to pricing policies, an increase in public transportation pricing is not easy as it is a collective transport mode which aims to leverage wellbeing and economic growth. In addition, rising prices would even generate a modal shift relinquishing public transportation use for the sake of private vehicle. Hence, pricing rises should be significantly and rationally considered.

Apart from that, a variance in demand of public transportation does not directly mean an improvement in subsidies and federal investment involvement. In other words, whether public transportation demand increase, the economic contribution of users to the system would also increment, that is, without raising prices.

Furthermore, in order to increase demand in these public services, there are many mechanisms. For instance, state investment grants willing to promote an integrated transport system are emerging to customized prices, thus more adequate price policies per use and in accordance with the individual mode of transport taken[34]. This integrated transport system is a strategy that still requires subsidies from transport operators towards an economic trade off in the whole system. Not to mention that multimodal transport system affects to fare revenues in many ways; as commuters will pay for more expensive travels due to the fact that the whole transport system would include a higher number of contributors among Mobility as a Service, fare revenues will perceive a growth.

To put the matter in a nutshell, farebox recovery rate declines with an increase of public transportation' demand [35].

Another matter of considerable interest is the fact related to investment policies and resulted subsidies in public transportation system, aligned to the investment in the construction of transport infrastructures as they are operation costs and so they affect to the obtained farebox recovery rate increasingly. For this reason, it should be mentioned that this master thesis assumes to discuss about the existing public transportation

[33] S. Saurí, 2017, Regió Metropolitana de Barcelona, Nous reptes en la mobilitat quotidiana: Polítiques públicuqes per a un model equitatiu i sostenible. *Conceptes clau i oportunitats de les vies de finançament del transport públic metropolità*. Pg 59-141

[34] G. de Rus, 2012, *Economía del Transporte.*

[35] R. Riol and A.Obiols, 2012, Materials CiP, *El futur immediat del transport públic*

infrastructures because if this report included the financial terms associated to new infrastructure, there would have considered long term return in investment for it. This study aims to analyse how subsidies or public funding variate due to an upward or downward demand tendency.

D.4.2. Subsidising theoretical index

Aligned to the previous chapter, subsidy distribution model varies by means of transport modal shift, reason why this report defines a subsidized theoretical index through which each one of the following case studies will be categorized in accordance with their behaviour of transport distribution costs from local authorities[36].

$$K_s = K_{ATP} \cdot K_T \tag{8}$$

Where,

K_s; Subsidy index (%), which also is computed by means of the farebox recovery rate:

$$(100\% - F_{rr}) \tag{9}$$

K_T; Traffic index, corrective factor according to the geographic position (%); Table 1.

K_{APT}; Public transport attracted demand resulted from carshare' emergence (%). For this reason, this subsiding theoretical model should be applied only for those scenarios where car share or even other disruptive new forms of mobility generate a favorable attracted index demand on public transportation.

[36] M. Sevrovic, Davor Brcic, Ph.D. and Goran Kos, Ph.D., 2015, Transportation costs and subsidy distribution model for urban and suburban public passenger transport

Table 1 Corrective factor according to fleet size, geographical position and membership magnitude

K_T; Traffic index, corrective factor according to the geographic position (%)	
Isolated regions (Poor interconnections between different transport modes)	1-0.9
Exceptionally non-transit	0.8-0.7
Suburban	0.6-0.5
Transit	0.3-0.4
Exceptionally transit	0.2-0.1
Integrated multi-modal system: Completely transit (without stopping)	0

D.5. General carsharing effects on Downs-Thomson Paradox

Apart from farebox recovery rate establishment in each city according to their particularities in transportation demand and behavioural shift among different alternatives modes of mobility, this report also aims to explore how modal choice impacts on the generalized costs of transport network. Still, carsharing implementation alters the balance between collective and individual transportation modal choice and furthermore the economical trade-off also shifts.

Therefore, in efforts to understand the effects of carsharing on the public transportation funding, Downs-Thomson Paradox [37] will allow this report to analyse different scenarios in which carsharing has been implemented and has driven different valuable effects to explore as they will, at a later stage, categorize the behaviour of several real cases.

D.5.1. Generalized case - Trade-off between collective and individual costs

As a matter of fact, the demand in public transportation does not remain constant. In fact, these last few years it has experienced an increase, reason why most of the mechanisms to adopt public transportation result from behavioural modal shift considering different alternatives or as the unique option to commute. Therefore, strategies to stimulate public transportation use is by means of offering lesser generalized costs[38].

Regarding the behaviour of marginal costs of both alternatives; private vehicle and public transportation, a particular mention should be made of the upward tendency of public transportation marginal costs and the downward tendency of marginal private vehicle costs with a rise in demand of each mode respectively (Downs-Thomson Paradox).

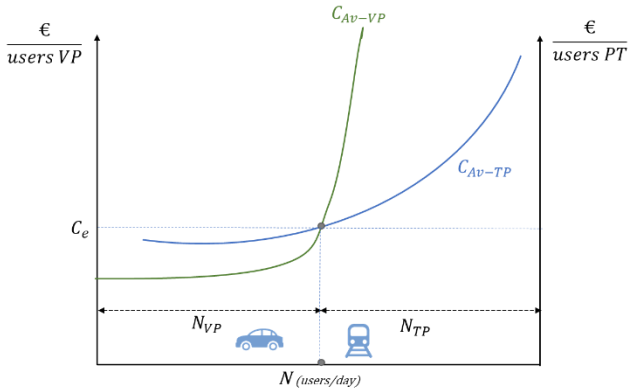
[37] Downs-Thomson Paradox (Mogridge et al., 1987) determines the trade-off between individual and collective transportation modal choice as well as the balance of the average costs perceived by of travelers among both alternatives. In addition, Downs-Thomson Paradox established that the behavior of public transportation average costs are subjected to economies of scale, whereas the private vehicles do not.
[38] Carlos F. Daganzo, 2010, Public Transportation Systems: Basic Principles of System Design, Operations Planning and Real-Time Control, Module 2, Pg 2-10: Comparison between Individual and Collective Transportation Modes.

Furthermore, trade-off between private vehicle and public transportation must be considered by the fact that public transportation is subject to economies of scale.

Although the trade-off financial theoretical model is changeable in accordance to investment strategies in efforts to promote private vehicle or public transit usage[39], it will be determinant to discuss modal choice and financial impacts balance as a result of the emergence of shared mobility services.

Furthermore, as the analysis of Downs-Thomson Paradox (Mogridge et al., 1987); Figure 10, exhibits the trade-off between individual and collective transport corresponds to the joint of both functions. The divergence of policy regulations seeking to promote one alternative rather than the other will experience a shift in this equilibrium joint. So, this variable parameter, open to discuss above, will provide valuable information to categorize the behavioural shit due to car share.

Figure 10 Downs-Thomson Paradox



Source 10 Elaboration: Author's own. Paradox (Mogridge et al., 1987)

Where;

C_{Av-TP}; public transit users average costs ($\frac{€}{users\ PT}$)

C_{Av-VP}; private vehicle users average costs ($\frac{€}{users\ VP}$)

N; number of travelers into the system per day (users/day)

N_{VP}; number of users travelling by private vehicles per day (users/day)

[39] R. Riol and A.Obiols, 2012, Materials CiP, *El futur immediat del transport public.* Module 5, Pg 23: *Tretze propostes d'estímul de la demanda*

N_{TP}; number of users travelling by public transportation per day (users/day)

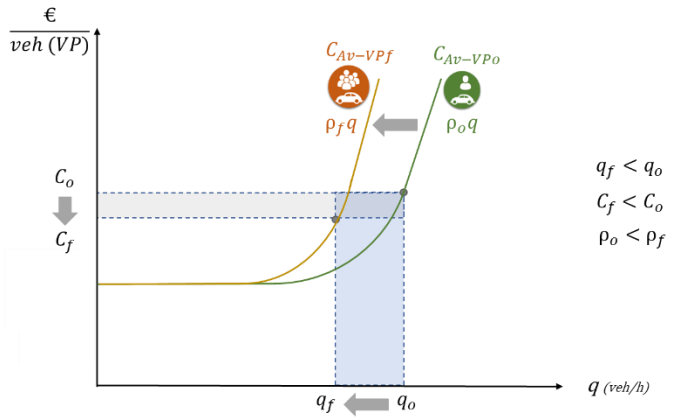
C_e; average costs equated to the equilibrium point ($\frac{€}{users\ TP/VP}$)

D.5.2. Variances among private automobile costs

I. Understanding the switching behaviour of the economic curve among private automobile

One of the key findings derived from the implementation of carsharing in any city is the private vehicle replacement in detrimental of the personal automobile mass. With this result in consideration, although many drivers faithful to automobile are attracted to new disruptive modes such as carsharing, the number of commuters remain the same. For these reasons, the theoretical model first poses the question whether there is an effect to the single-occupancy per vehicles driven by the fact that those commuters who came from the highway have been attracted by shared mobility modes.

Figure 11 Occupancy per vehicle, transit flow and cost effect due to carshare



Source 11 Author's own

Where;

$C_{Av-VPo/f}$; private vehicle average costs before/after car share' emergence ($\frac{€}{users\ VPo/f}$)

$C_{o/f}$; average costs equated to the equilibrium point before/after car share' emergence ($\frac{€}{users\ VPo/f}$)

$\rho_{o/f}$; number of users per vehicle before/after car share' emergence (users/veh)

$q_{o/f}$; number of vehicle per hour before/after car share' emergence (veh/h)

The result of the previous analysis; Figure 11, concludes a shifting behaviour in the automobilism. In other words, if carsharing adds value to automobile users, the occupancy of passengers per vehicle increase while number of vehicles exhibits a decline and hence, their average costs also diminish. That is to say that the theoretical model experiences a switching behaviour of the curve in accordance with the behavioural shift of costs represented in Figure 11, which corresponds to the following first scenario reported at chapter D.6.1.

Not to mention that the previous finding will also permeate the behaviour of automobile average costs on the Downs-Thomson Paradox (Mogridge et al., 1987).

II. Leverage the switching behaviour of private vehicle costs to the Downs-Thomson Paradox

Thanks to the previous finding, this report proceeds to determine the behaviour of private vehicle costs in Downs-Thomson Paradox (Mogridge et al., 1987) as well as to determine the theoretical effects due to car share, whether public funding is committed to promote one mode or the other.

With this aim in mind, some considerations should be primarily established, and some of them have already been reported.

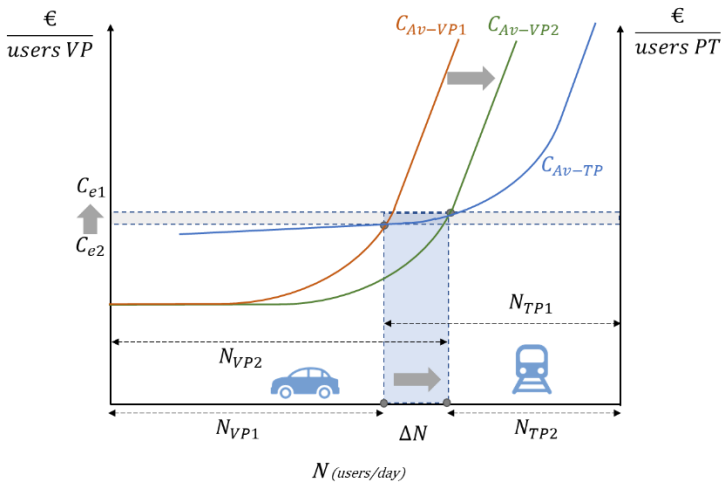
(i) As public transport has economies of scale there is a clear rationale towards investment policies promoting public transit.

(ii) The user average costs assume diseconomies of scale among private vehicles due to extra costs derived from congestion and also taking into account the economies of scale reported previously in public transit.

III. Financial shift with policy regulations seeking to promote the use of private vehicle

Whether national and regional governments establish policies and investment strategies related to the construction of road and highway' infrastructures with the aim of promoting the use of private vehicles, the average cost of these modes experience a shift from C_{Av-VP1} to C_{Av-VP2} observed in Figure 12, and it also results in an increase of the number of private vehicles, N_{VP}; per day by an amount of ΔN. Doing so, the demand of public transportation declines reaching lesser users per day; N_{TP2}, though the previous scenario had $N_{TP1} = N_{TP2} + \Delta N$.

Figure 12 Trade-off between private vehicle and public transportation average costs



Source 12 Down-Thomson Paradox (Mogridge, 1997)

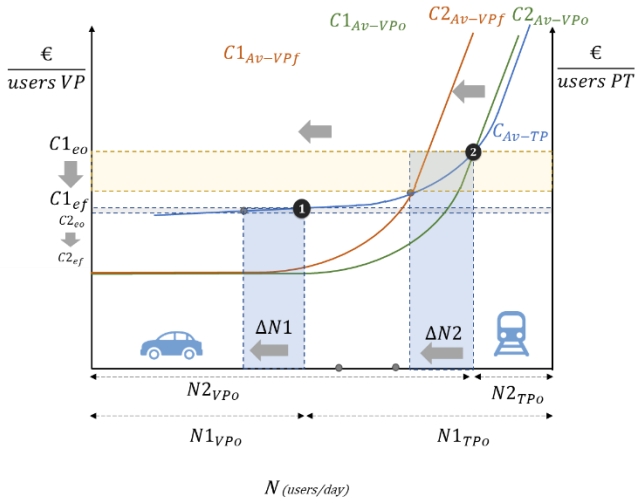
Likewise, many decisions of governments that are willing to boost sustainability and environment protection go along with strategic funding policies on public transportation. In this scenario, average costs in public transportation, C_{Av-TP}; figure out a decline as the number of travelers by public transportation increase.

IV. Equilibrium trade-off contributes distinctively to automobile shifting costs

Additionally, different networks and cities respond distinctively in accordance to several parameters such as the public transit network size, territorial spread and the mobility

patterns in each place. Figure 13 shows a considerable average cost variance between distant equilibrium points; cities and municipalities where regulations are committed to shift private vehicles onto sustainable mobility, any alteration in personal vehicle patterns is translated into a considerable decline of average costs ($C1_{ef} - C1_{eo}$). Otherwise, transport networks and cities where highway and automobilism are fundamental for commuting, any variation among share of mobility modes experience an insignificant decrease of average costs ($C2_{ef} - C2_{eo}$).

Figure 13 Different variance ratios: Trade-off between private vehicle and public transportation average costs



Source 13 Elaboration: Authors' own. Down-Thomson Paradox (Mogridge et al., 1987)

At the same time, related to the previous expression that determines public subsidies as a function of average and marginal costs (3), another matter of fact is that cities where there is a minor public transit usage and major private automobilism investment (equilibrium point 2 at Figure 13) any variation among share of mobility modes would require more subsidies rather than in cities where public transport usage was major and personal vehicles are lower (equilibrium point 1 at Figure 13).

$$C2_{ef} - C2_{eo} < C1_{ef} - C1_{eo} \quad (10)$$

D.5.3. Variances among public transit costs

I. Understanding the switching behaviour of the economic curve among public transit

As repeatedly mentioned in this report, public transit holds economies of scale. Nevertheless, this chapter aims to characterize the changeable behaviour of public transportation average costs with an alteration of its demand share.

In efforts to gain in-depth perspective of cost shifting rules, all case studies will agree with the definition of the following variables in order to understand the behavioural shift of public transportation as well as determine some contributing factors to differentiate both caseloads.

C_{Av-TP}; public transit average costs car share' emergence ($\frac{€}{users\ TP}$)

C_{Mg-TP}; public transit marginal costs car share' emergence ($\frac{€}{users\ TP}$)

$D_{o/f}$; Public transportation share of demand (users/day)

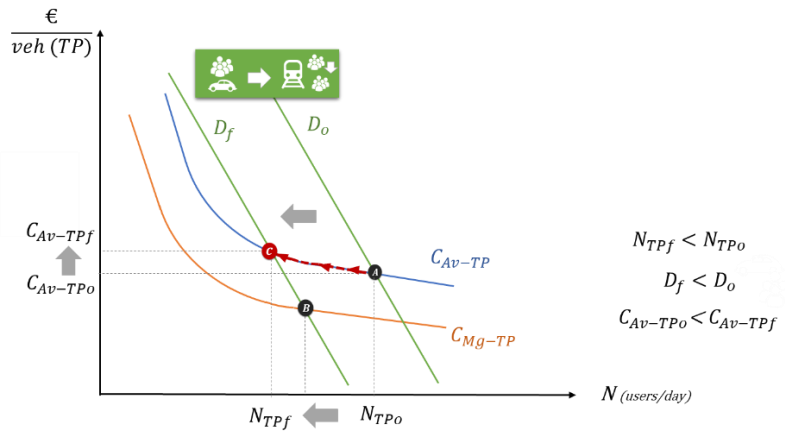
$C_{o/f}$; average costs equated to the equilibrium point before/after with a decline in demand ($\frac{€}{users\ VPo/f}$)

$N_{PTo/f}$; public transit users before/after with a decline in demand ($\frac{€}{users\ TPo/f}$)

On contrast to private automobile, public transit, as a result of car share, can experience distinctive variances;

(i) Car share results in a decline of the public transportation demand

Figure 14 Switching behavior of average costs with a decline of the public transportation demand

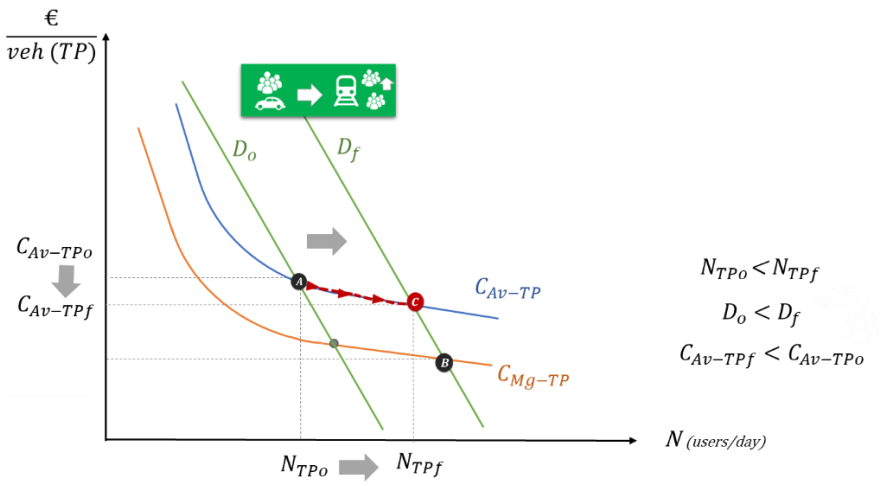


Source 14 Elaboration: Author's own. Economical transport model (G. de Rus, 2012)

The exhibit above; Figure 14, represents the case in which new users in car share new not only come from private vehicle, hypothesis that has been assumed transversally during the theoretical financial model, but they have also been persuaded from public transportation thus this latter mode of mobility experiences a decline in its demand share. In face of this downward behavior of the demand, the performance of average costs concludes a switching from joint point A to C, all along the average costs. Hence, this sub-scenario results in detrimental to public transit use, car share results substitute mode to public transportation. Nevertheless, considering both average and marginal costs in the expression, a decline in public transit demand delivers a joint divide between points A and B.

(i) Car share results in an increase of the public transportation demand

Figure 15 Switching behavior of average costs with an increase of the public transportation demand



Source 15 Author's own. Economical transport model (G. de Rus, 2012)

On the other hand, previous analysis; Figure 15, allows this report to conclude that whether car share not only attract users from private vehicle, but also inducts more demand in public transportation so that car share results favourable to public transit usage. This scenario is a transitioning model onto sustainable mobility; including both carsharing and public transit. In other words, this sub-scenario concludes that car share is complementary to public transportation. In particular, an upward tendency of public transit demand as a result of carsharing services exhibits a decline among average costs.

II. Leverage the switching behaviour of public transit costs to the Downs-Thomson Paradox

In order to leverage the switching behaviour of public transit average costs to Downs-Thomson Paradox whether the demand share of this alternative results on favourable or disadvantageous manner, the behavioural shift of the curve is superposed to the downward perspective of the private vehicle' financial curve. These distinctive results are further detailed in chapter D.6.2.

D.6. Carsharing theoretical financial scenarios

To gain deep knowledge about the impact of carsharing among public transportation costs, this section leverages the previous theoretical questions about the effects of these innovative modes of mobility on Downs-Thomson Paradox (Mogridge et al., 1987) in the direction to determine all the different behavioral scenarios.

Furthermore, to accomplish a trade-off between private vehicle and public transportation trade-off by, this report assumes that the behavioral shift will not be uniquely among these two alternatives of mobility; with the introduction of new modes of mobility such as carsharing, shifting gap between before-after analysis can also adopt newly transport modes. Additionally, applying Downs-Thomson Paradox to the reality of shared mobility, this analysis also assumes that public transportation remains its economies of scale as well as private vehicle upward average cost tendency with its number of users.

D.6.1. Scenario 1: Carsharing exhibits a decline of private vehicle users. Hypothesis: public transportation users remain constant

At first stage, this scenario holds several hypotheses in accordance to the theoretical behavior seen previously:

(i) This latter consideration is aligned to the general finding which states that carsharing services affects in a clear relinquish of private vehicle' acquisition or ownership;

$$N_{VP}^{after\ carsharing} < N_{VP}^{before\ carsharing} \quad (11)$$

(ii) The number of public transportation users per day remains constant, N_{TP}, reason why leads it to be characterized as unrealistic scenario. Thus, all potential car share users come from the private vehicle, reason why this scenario defines the following additional variables:

ΔN_x; number of users per day shifted as a result of the emergence of carsharing services, whose commuting mode is x; neither automobile nor public transportation.

In this scenario, all ΔN_x came from private vehicle use before the implementation of car share.

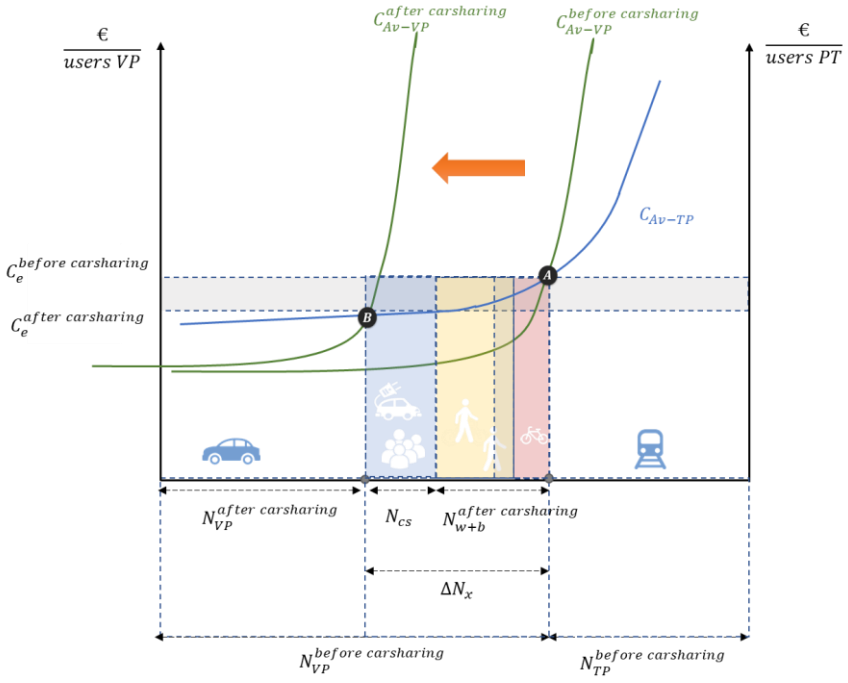
N_{cs}; number of carsharing users per day. In this scenario, once again, those users will be attracted by automobilism.

$N_{w+b}^{after\ carsharing}$; number of travellers inducted to commute by walking either by bicycle, which have been inducted as a result of the implementation of carsharing services.

$$\Delta N_x = N_{cs} + N_{w+b}^{after\ carsharing} + \cdots + N_x \tag{12}$$

Furthermore, Downs-Thomson Paradox (Mogridge et al., 1987) for this particular scenario superposes the switching behavior of private vehicle curve as represented in Figure 16;

Figure 16 Mogridge Paradox analysis. Scenario where carsharing implementation causes a decline of private vehicles' users.



Source 16 Elaboration: Author's own. Downs-Thomson Paradox (Mogridge et al., 1987)

As a result, private vehicle average costs conclude a decline in the trade-off costs with the implementation of car share services (from point A to B at Figure 16);

$$C_e^{before\ carsharing} > C_e^{after\ carsharing} \quad (13)$$

In other words, as reported before, the effect of private vehicle average costs due to car share is a reduction of the automobiles but of the users. Thus, the flow of automobiles per hour experiences a decline, thereby the economic trade-off shows a downward incline.

Nevertheless, this scenario assumes that the demand in public transit remains constant, this scenario could be differentiated between two sub-scenarios, according to the percentage of carsharing implementation over the whole presence of private vehicle in the system. In other words, when carsharing use outnumbers personal vehicle considerably, not only the occupancy increases, but the vehicles per hour are also significantly reduced. In a sub-scenario in which this replacement is notorious, public transit users could be attracted by these innovative services. This sub-scenario does not correspond to the Scenario 1 where public transit demand remains constant.

Otherwise, if the percentage of carshare is depreciable over private vehicles, it makes sense to assume the use of public transportation behaves constant. All in all, scenario 1 would correspond to the latest assumption.

In addition, for those transport networks in which private vehicle highways and infrastructures are at such advanced stage of territorial structure that they denote a political framework more likely to contribute to the deployment of automobilism industry rather than promoting the increasing use of sustainable transportation, the switching behavior of costs would experience a more prominent decline in costs while implementing a car share system.

D.6.2. Scenario 2-3: Carsharing result on a decline of private vehicles users and variance in public transit demand share

In order to represent a more accurate model of the real effects of carsharing introduction on public transportation and private vehicle alternatives, the following scenarios analyses the variation of public transportation demand, both upward and downward.

Among those public transit users that do change their behavior as a result of carsharing, there are some preliminary considerations that should be noted:

(i) In both these scenarios, the study adds another boundary condition to the first scenario, which says that carsharing emergence drives a reduction of private vehicle usage;

$$N_{VP}^{after\ carsharing} < N_{VP}^{before\ carsharing} \quad (14)$$

(ii) Still, both scenarios consider diseconomies of scale in private vehicles whereas in public transportation economies of scale.

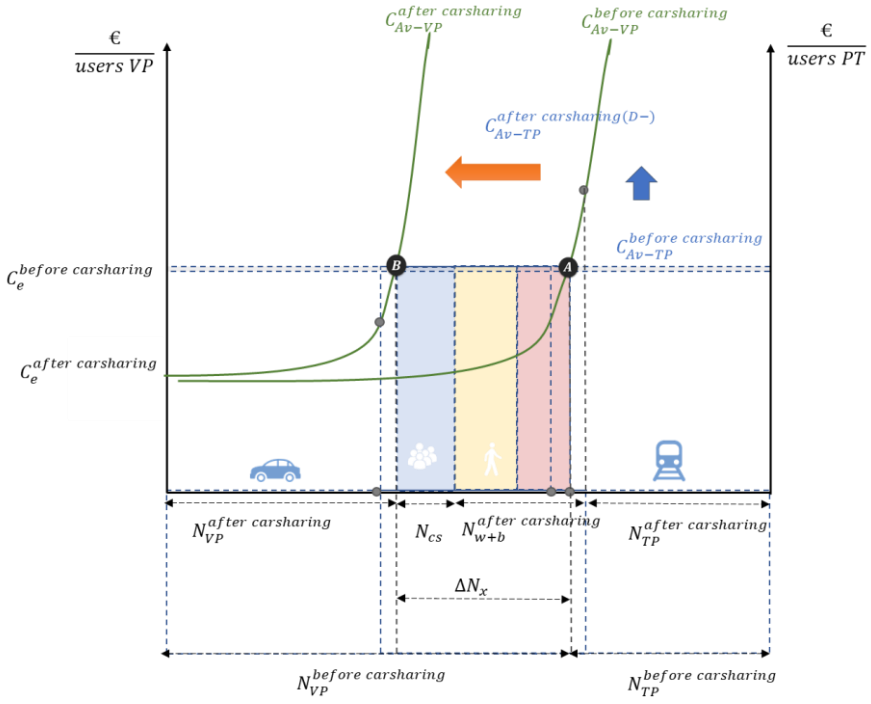
(iii) The number of public transportation users per day does not remain constant; N_{TP}. Thus, both scenarios derived from these lately hypotheses exhibit that carsharing membership does not only come from private vehicle' ridership, other alternatives such as public transit attractiveness either healthier modes of mobility seem altered by means of car share. At the same time, both scenarios conclude that results in a car share conclude a complement either substitute contributing role to public transportation.

I. Scenario 2: Carsharing result on a decline of private vehicles users and a decrease of public transportation demand

In addition, this report notes that broadly the count of car share members reducing their public transportation scenario outnumbers the count of those increasing their use, which correspond to this scenario in which public transit share experiences a decline; Figure 17. In other words, this scenario means that public transit travelers are partially persuaded by the advantages that carsharing services offer.

$$N_{TP}^{after\ carsharing} < N_{TP}^{before\ carsharing} \quad (15)$$

Figure 17 Scenario where carsharing' implementation causes not only a decline on private vehicles, but also a decrease of PT demand



Source 17 Elaboration: Author's own. Downs-Thomson Paradox (Mogridge et al., 1987)

Nevertheless, other parameters suggest playing a determining role while characterizing the downward tendency of public transit demand such as the fleet size within the city, the fleet parament practices and existing member-vehicle ratios. Not to mention the scope of analysis considering urban and interurban areas, which are deeply analyzed through several real case studies at *E.3.*, is another decision-making variable while categorizing the effects of car share inducted membership.

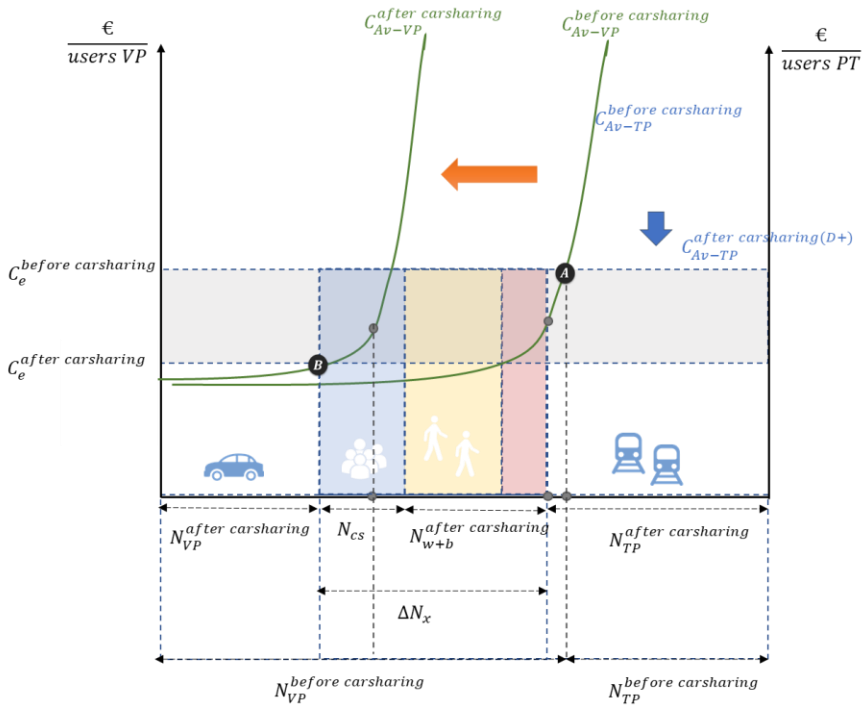
II. Scenario 3: Carsharing result on a decline of private vehicles users and an increase of public transportation demand

Otherwise, public transit demand can experience favorable results by means of car share as interurban areas many times are out of the scope of carsharing due to the low density of transit flow so that in those scenarios car share could conclude complementary mode to public transportation. In addition, multimodal integration between different alternatives of transport is willing to build a cohesive network complementary, so integrated pricing

policies as well as multimodal technologies could be other caseloads that delivers this latest scenario in which public transportation experiences an increase in its share of use. By way of explanation, car share users do not only attract private vehicles drivers, but also shift private vehicles onto public transportation, which is a clear example of successful change of patterns towards sustainable mobility.

$$N_{TP}^{after\ carsharing} > N_{TP}^{before\ carsharing} \quad (16)$$

Figure 18 Scenario where carsharing' implementation causes not only a decline on private vehicles, but also an increase of PT demand



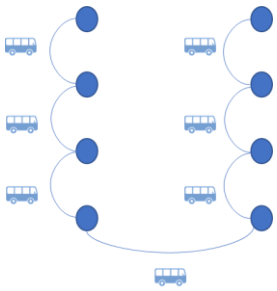
Source 18 Elaboration: Author's own. Downs-Thomson Paradox (Mogridge et al., 1987)

Furthermore, whether public transportation demand grows, shifting gap, ΔN_x; expands prominently, whereas when public transportation decreases, the shifting gap is squeezed.

D.7. Transport networks disruption because of shared mobility

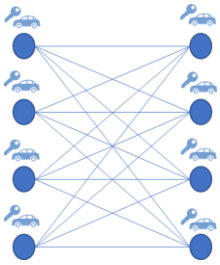
Carsharing emergence turns up with network trade off as these new services provide users behavioural shift and so new consolidation networks. Before the introduction of shared mobility, public transportation was mostly understood as peddling networks, but the emergence of carsharing has also disrupted the optimal distribution of goods and travellers and therefore the trading-off between local to global accessibility. That is to say, in the first place carsharing network used to provide many-to-many distribution network as their users pick up a vehicle at one of many predetermined locations (pods), and then return it to any pot when finished. However, nowadays, with the advent of MaaS paradigm, there are other preferred parameters that led to an evolution of transport networks.

Figure 20 Peddling - Public Transportation



Source 20 Author's own

Figure 19 Many-to-many - Carsharing



Source 19 Author's own

Besides, many-to-many consolidation terminals of carsharing services puts forward the debate about the optimal distribution of carsharing pods in order to broader cover all across the city with transport service and connectivity. In such manner, depot optimal distribution becomes crucial to deliver a preeminent level of service to users and hence lower travel costs; C_u.

Therefore, as this report aims to establish a comparison between public transportation and carsharing costs, distribution coverage turns up as another factor of financial and usage effects between both modes. Withal, carsharing pods strategical spread will be

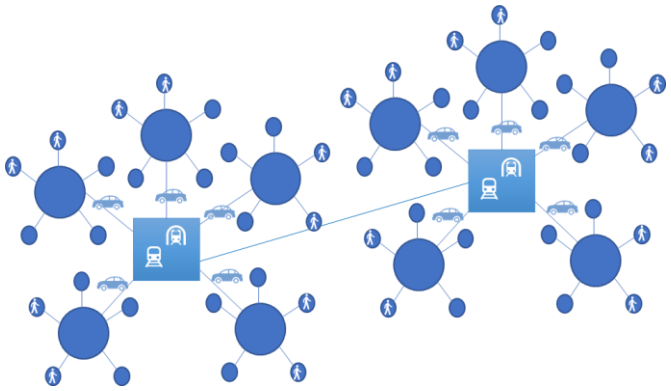
vital to provide multi-modal transport system in the cities as it will be further studied at a later stage of this report.

Nonetheless, multi-modal transport system turns into a fundamental layer of Mobility as a Service paradigm as they invite new modes of mobility to be inclusive and collaborative with traditional ones; such as public transportation. To this extent, carsharing pick up pods distribution among the territory plays a decisive role to generate an integrated and multi-modal transport system with the hand of public transportation. In this scenario, carsharing network mentioned before serving as Many-to-Many would evolve in Hub & Spoke distribution model.

Additionally, strategical location of carsharing pods transitioning the transport network system from a many-to-many to a more user-convenient distribution also induct a behavioural shift.

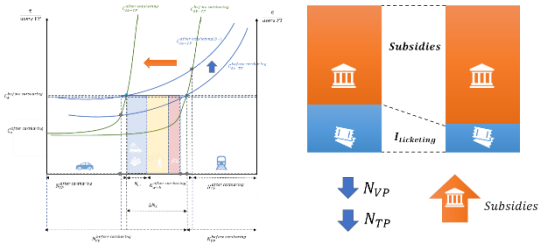
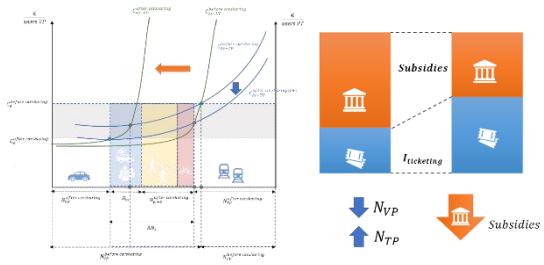
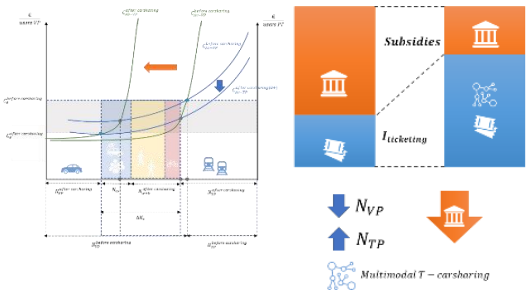
As longer travelled distance seemed to be prejudicial to carsharing modal choice, Hub & Spoke as multi-modal advantageous transport system breaks up with this behavioural pattern, providing combined modes of transport; both public transportation and carsharing as public transportation has a wider coverage across the territory and would serve as hubs to interconnect different regions and cities. At the same time, from a financial perspective, a more *Hub & Spoke* car share distribution means a more complementary mode to public transit, but also a shift of economical patterns closing even more the gap between the willing to pay for commuting and the real prices as interconnected systems are more customized services. Furthermore, the transition from Many-to-Many -local accessibility- to Hub & Spoke – global accessibility – puts forward a more customer centric distribution.

Figure 21 Transport network resulted to public transportation and carsharing multimodality



Source 21 Author's own

D.8. Public transportation funding theoretical effects

PUBLIC TRANSPORTATION FUNDING THEORETICAL EFFECTS	
Public transportation funding and the behavioral shift of the requiring subsidies as a result of a inducted by the implementation of carsharing; Subsides and the income covered by means of ticket sales are subjected to public transport modal shift.	
Scenario 2: D.6.2.I	
Carshare results substitute mode to public transit; Whether carshare impacts in detrimental to public transport usage, public funding and required subsidies increase to cover all the operational expenses to keep public transit functioning. At the same time, in this scenario, the income incurred from ticket sales declines as the density of users per public transit vehicle also decreases.	
Scenario 3: D.6.2.II Many-to-many	
Carshare results complementary to public transit; Those scenarios where shared mobility concludes a complementary or favorable contribution to public transit, it inducts an increase of this latter mode of transport. As subsidies and public funding is subjected to further optimization while an upward tendency of the demand, this scenario contributes to close the financial gap existent in public transportation.	
Scenario 4: D.6.2.II together with a multi-modal transport network (D.7)	
Carshare results complementary to public transit more prominently as a result of multi-modal integrated transport system; In this case there is a similar impact to the previous scenario, but it is also adds the condition that transport system counts with an integrated multi-modal cohesion, which is indirectly translated into a more customized pricing results – pay per use or pay per combined modes of transport - although this report assumes prices remain constant. As a result, the more multi-modal facilities existent into the system, the less public funding is required to subsidize.	

E.TRANSPORT MODAL SHIFT ANALYSIS

E.1. Drivers and decision-making variables

E.1.1.Success drivers of carsharing usage

Innovative MaaS advancements, such as shared mobility, are persuasive opportunities as well as inspiring technological experiences for urbanites to emerge to new socioeconomic models among metropolitan cities. In the same way, carsharing offers quick-wins for commuters, which invite shifting their travel patterns and behaviours. This suggests exploring not only the success factors that engage more users to join carsharing services, but also analyse the effect on modal shift due to future mobility patterns of users.

Carsharing services provide commuters all the benefits of private vehicle without the attendant high fixed costs such as purchase, insurance and maintenance. These new models of mobility give customized and flexible pricing management by means of adopting pay-for-use possibilities. Hence, they differentiate customer experience according to the distance or time employed.

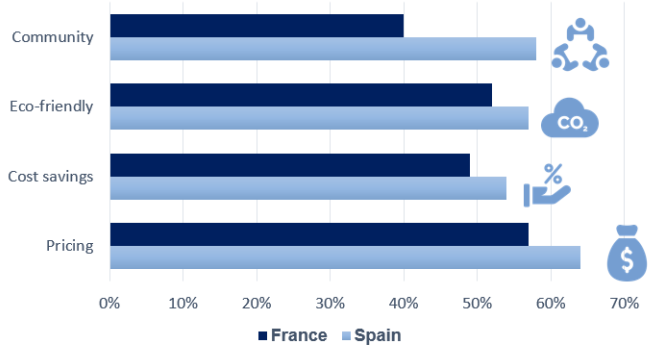
Sum to the fact that pricing is well-balanced according to the usage, the accessibility that carsharing rises allows reduce average travelled time. As a matter of fact, carsharing services disrupt the transport network system, transitioning it from local to global accessibility.

Additionally, urbanites deserve connectivity and convenience from getting from A to B, and hence, carsharing is an example of ubiquitous services that offer these benefits. This is still increasing for youngest commuters who seek flexibility, accessibility and seamless connectivity. Digital era allows carsharing users to take advantage of prominent location of carsharing compared to other mobility services.

Therefore, these benefits invite further commuters to use carsharing mobility services, but it should be considered all the boundaries to better understand urbanites patterns. For this reason, other parameters such as flexibility, travelled distance and intermodality would be further analysed on the following sections of this report.

As commuters the factors that drive ourselves to take collaborative economy are pricing, cost savings, eco-friendly and since they build community; Figure 22. For instance, Spain as well as France consider that the customization pricing that carsharing allow is the main driver to use these services, by 64% and 54% respectively.[40]

Figure 22 Factors influencing participation in the collaborative economy (European countries: France and Spain)



Source 22 Authors' own.

Diversely to European population, United States carsharing members employed these services mostly to serve basic needs, then because of long distance recreational trips.[41]

In addition, other benefits or drivers that lead citizens to adopt carsharing services besides cost savings, which have already been mentioned above; Figure 22, there are other quick-wins of these mobility services such as a decline of travel time, traffic congestion and an easing of parking externalities. Furthermore, carsharing services improve the well-being and strengthen healthy habitudes, reduce the harm of environment and build a well-balanced and efficient automobilism usage.

[40] "Assessing the size and presence of the collaborative economy in Europe". European Commission, Robert Vaughan and Raphael Daverio PwC UK April 2016

[41] Peer-To-Peer (P2P) Carsharing: Understanding Early Markets, Social Dynamics, and Behavioral Impacts

E.1.2.Carsharing Customer Profile

For further understanding the reasons of transportation modal shift due to carsharing services implementation, this report aims to know better by whom is taken as well as their patterns and trip purposes. Although there is any clear evidence about these insights, it has been observed that carsharing user is predominantly male, though gender did not used to be a distinctive pattern, reaching 69.0% among Europe countries. On the contrary, North America figured out in favour of females (57.0%).[42]

Also, those who tend to adopt more carsharing services are between 25 and 44 years.

Likewise, carsharing users have a distinctive socio-economic profile and about 60% hold advanced degrees.[43,44] Other observed customer patterns are such that users live in households and holds middle-upper income households[45]. In particular, the 23.2% of users have an income of 2,001-3,000 euros per month, and the 17% have 3,001-4,000 euros per month among French cities[46]. Hence, the 76% of carsharing members are full-time professionals[47].

Additionally, customer profile highlights those users of non-car forms of urban transport (i.e. public transport, walking and cycling).

I. Corporate carsharing

In order to gain a more accurate understanding of the most common customer profile of carsharing, this section additionally reflects upon corporate or business carsharing as

[42] Carsharing: Evolution, Challenges and Opportunities, Centre for Transport Studies, Imperial College London, September 2014
[43] Millard-Ball, A., Murray, G., ter Schure, J., Fox, C., and Burkhardt, J. (2005) Car-sharing: When and how it succeeds. Transit Cooperative Research Program Report #108. Transportation Research Board.
[44] Frost and Sullivan (2014) Strategic Insight of the Global Carsharing Market. Report #ND90-18, June 2014.
[45] Dill, Jennifer, Howland, S. MacNeil, N. (2014) Peer-to-Peer Carsharing: A Preliminary Analysis of Vehicle Owners in Portland, Oregon, and the Potential to Meet Policy Objectives. Paper presented at the 93rd Annual Meeting of the Transportation Research Board, Washington DC, January 2014.
[46] Enquête nationale sur l'autopartage l'autopartage comme déclencheur d'une mobilité alternative à la voiture particulière. Janvier 2013.
[47] Enquête nationale sur l'autopartage l'autopartage comme déclencheur d'une mobilité alternative à la voiture particulière. Janvier 2013.

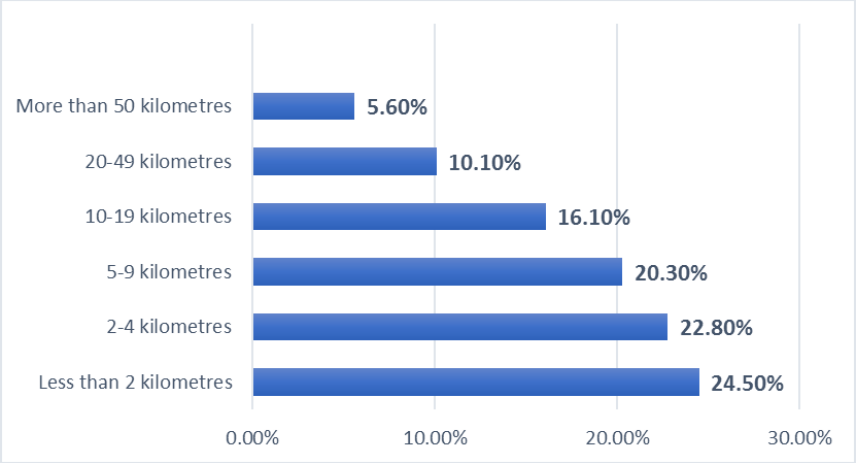
another success drivers of carsharing systems. In this case, shared mobility goes deeper among employees and departments. Although this form of carsharing firstly emerged in 1995 in Dutch, Flexcar started in North America in July 2002 and then Zipcar in 2004, lately, within three months, it had enrolled more than 50 companies. (Shaheen et al., 2009) and nowadays any carsharing company offers business option. Furthermore, there are evidence that suggest that operators and members are growing, but also that this market sector is exceptionally profitable for carsharing operators. Additionally, it was identified as second most profitable sector by 31.8% of North American nations, behind neighbourhood roundtrip market at 54.5% (Shaheen and Cohen, 2012).

E.1.3.Territorial users' decision-making variables

Another decision-making' variables that commonly invite commuters to adopt carsharing services are the distance to be travelled and the level of presence into urban fabric where the territorial connectivity and public transport network are better than interurban areas. According to Autolib' carsharing service in Paris experience, only the 5.5% of members are from metropolitan areas and just the 11.6% are residents in urban areas with lesser than 300,000 habitants. Hence, those whom adopt carsharing mostly, at 55.2% arise from urban areas with more than 500,000 habitants with public transportation network available. All these led this report to explore deeper how multimodality effects on users' patterns.

Additionally, as it has been mentioned before, the travelled distance is another determining factor among carsharing users. In other words, the closeness between workplace or education centre and the residence facilitate in more or less degree the usage of carsharing or other modes of transport. As reported below at Figure 23, French cities show up that whom daily travel less than 2 kilometres mostly represent carsharing' users by 24.5%. Consequently, users who usually have between 2-4 kilometres to be travelled by 22.8%.

Figure 23 How distance to be travel is a decision-making parameter to become carsharing member



Source 23 Authors' own. Data: Enquête Nationale Autopartage 6T-Bureau de recherche

E.1.4.Carsharing versus other mobility alternatives balance

The analysis of carsharing gaining a foothold in mobility system goes through considering all carsharing typologies according different decision-making parameters: distance travelled, flexibility and cost. Additionally, the matrix below; Figure 24, considers different models of carsharing compared to other mobility services at differentiated pricing and tariff, classified by the flexibility they offered to users as well as its degree of usage according to the distance to be travelled.

Figure 24 Flexibility-Distance Travelled-Cost Carsharing Balance Matrix

Source 24 Authors' own

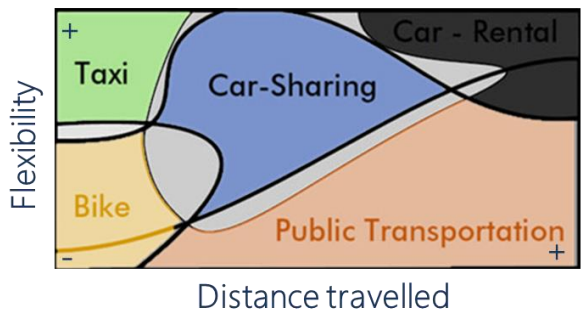
This previous study characterizes some of the decision-making factors that influence commuters to use carsharing, and it can be highlight that the distance, and hence the variation in usage areas from urban to regional is considerably differentiated. In that sense, suburbs and surrounding areas long-distanced from the core of cities require other type of more traditional carsharing (i.e. peer-to-peer either car-pooling) or even public transportation to access to city and then use other free-floating or station-based carsharing services. This fact also is due to the boundered spatial scope of carsharing services that cannot cater for longer drives.

Consequently, this also drives the analysis to figure out that carsharing is being increasingly growing in bigger cities where more commuters are giving up costs associated to car ownership. Otherwise, smaller cities are being catered for by more regional mobility operators.

The migration around cities is enormously increasing, reason why leads this report to consider the accessibility and connectivity between regional areas and main district areas or cities. Thus, this case study will be further evaluated since the intermodality or multimodality of diverse range of transport modes is open to further research.

Many sources and mobility experts believe that carsharing is becoming a complementary mode of transport to other alternatives in terms of flexibility and travelled distance. Each one of customer profiles analysed previously envisage their own mobility advantage features and decide how multimodality alternatives would fit better for them. With this in mind, carsharing becomes complementary to other transport alternatives in the following measures, (Schward Joachim. et al., 1999):

Figure 25 Carsharing and other transport modes coexistence



Source 25 Schward Joachim 1999

As it has been reported previously, other transportation modes are related with carsharing in terms of flexibility and distance to travel parameters; Figure 25. Nevertheless, there are other decision variables to adopt carsharing usage:

- Cost and individual economic situation influence citizens to consider transport alternatives.
- Although taxi almost always provides the shortest itinerary, it is the most expensive transportation mode, reason why it becomes weak in terms of distance to be travelled.
- Carsharing stations distribution and spread around the city also influence the citizens to adopt these services. It seems that when those are located in areas where there are parking difficulties, non-motorized lifestyle, high population density and multiuse of the land, carsharing usage is greatly perceived by users to adopt them.[48]

E.2. Carsharing generalized shifting effects

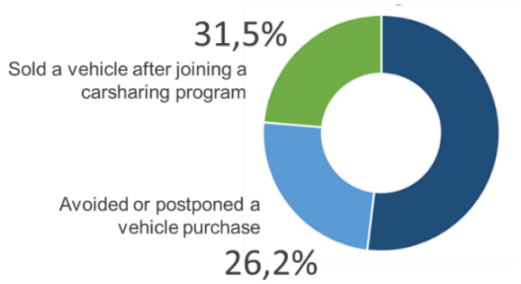
The impacts of carsharing can be diverged between transportation modal shift, environmental, land use, social and even economic effects. Nevertheless, this report is deeper focused on travel behavioural impacts that will further determine the investment indicators in public transportation. These services provide benefits such as find parking easily for those station-based services, access to the vehicle immediately and cater local travel needs, which attribute changes in commuters' daily experience as caused by the presence of and access to carsharing mobility services.

More than 40% of carsharing users affirm that the reason why they shifted their mobility behaviour is due to carsharing membership. In contrast, 60% consider that their change of pattern in mobility is caused by other occurrences among the path.[49] Furthermore, these results drive this report to delve deeper into the effects of modal shift motivated by shared mobility.

[48] Auckland Transport - Auckland Council Organization. Electric car share scheme. (https://at.govt.nz/projects-roadworks/electric-car-share-scheme)
[49] Enquête Nationale Autopartage 6T-Bureau de recherche.

E.2.1.Shifting users' behaviour to vehicle' non-ownership

Commuters affirm that they changed their use of transportation modes in response to carsharing services and individual benefits. One of the main MaaS' proposals is the emerge to decrease vehicles holding, and carsharing is a key-player in this transition as it offers some quick-wins conducive to supress personal vehicles. European cities conducted a significant shifting users' mobility patterns removing the need of purchasing a private vehicle or even postponing the purchase among European countries, reaching the following shares (Susan A, Shaheen et al., 2007):



More specifically, France experienced a decline of motorized mobility parallelly to carsharing implementation by 15-30%, and other 20-30% delayed the acquisition or purchase of private vehicles motivated by carsharing availability (N. Louvert et al.,6T-Bureau, 2013). This bolsters the percentages at European level reported before. What is more, these percentages are slightly different from North America, where reached 11-20% and 12-68% respectively.[50].

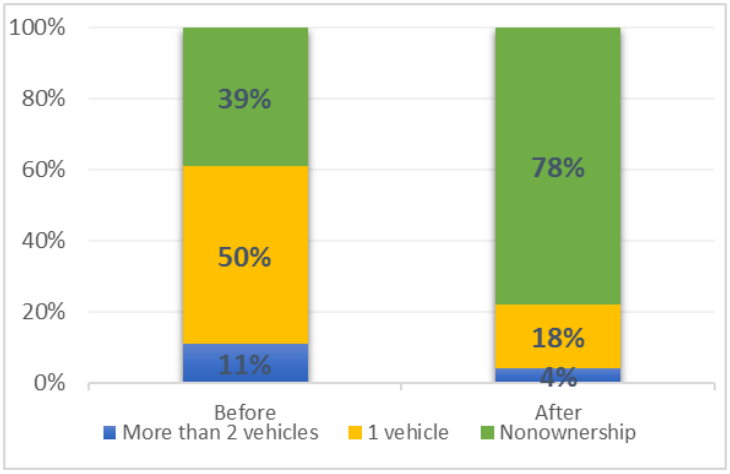
This change of customer patterns is susceptible to other parameters which are changing over time and are distinct among different countries by cause of political frameworks and regulations - fuel costs and transport regulations.

With this in mind, automobile' ownership is considerably diminishing because of carsharing evident quick-wins to users, so that in European countries each shared vehicle replaces 4-10 private vehicles[51] and each one economizes several parking

[50] Worldwide Carsharing Growth: An International Comparison. Transportation Research Record Journal of the Transportation Research Board. January 2008.
[51] ITS UC Davis, Worldwide Carsharing Growth: An International Comparison

stations[52]. Furthermore, this report, through carsharing before-after analysis, will be able to evaluate the variance of private vehicles' ownership.

Figure 26 Shifting users' mobility patterns removing the need of own a private vehicle



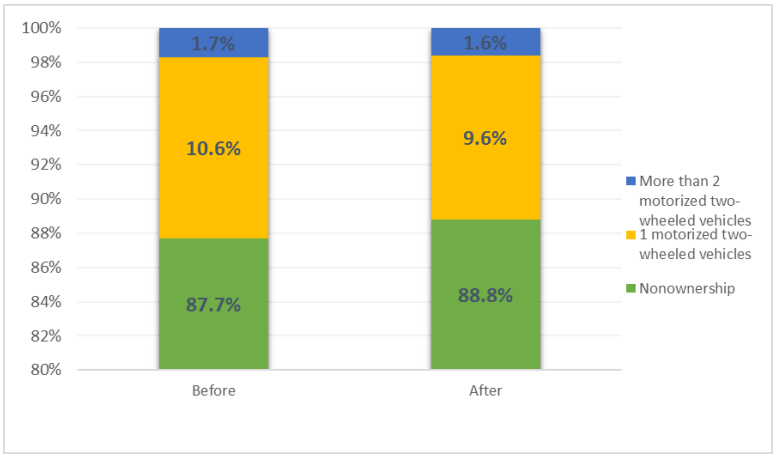
Source 26 Authors' own. Data: Enquête Nationale Autopartage 6T-Bureau de recherche

Moreover, the emergence of carsharing services concludes a reduction of the motorization rate in cities; those who had several private vehicles before, carsharing availability have significantly declined from 11% to 4%, and those who holded one private vehicle has emerged from 50% to 18%, increasing the rate of non-ownership share up to 78%. Indeed, from these data it is to be highlighted that the decline of vehicle ownership is by 36.07%; Figure 26.

Similar to the previous before-after analysis, motorized two-wheeled vehicles are also to be considered in this report, and hence they seem to experience a slightly decrease as a result of carsharing services. Nevertheless, raising tendencies of non-ownership coincide with private vehicles analysis, though slowly from 87.7% to 88.8%.

[52] 6T-Bureau de recherce, EPFL, 2010, "Et si les français n'avaient plus seulment une voiture dans la tête? Evolution de l'image des modes de transport", CERTU.

Figure 27 Shifting users' mobility patterns removing the need of own a motorized two-wheeled vehicle

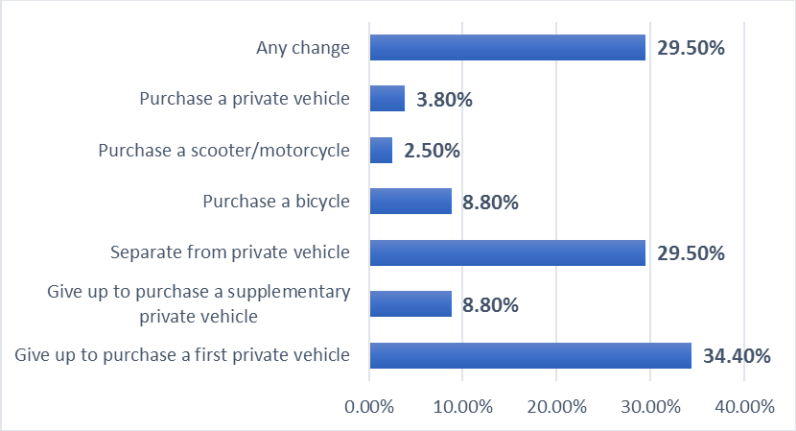


Source 27 Authors' own. Data: Enquête Nationale Autopartage 6T-Bureau de recherche

Furthermore, motorized two-wheeled vehicles purchase is especially concerned by most-frequency carsharing users. On the contrary, carsharing users show a tendency to purchase bicycles, independently to the frequency of their carsharing usage.

This report not only aims to explore the inducted modal shift, it also wants to understand the reasons that motivated users to change their patterns and how they behave lately to carsharing' subscription. Indeed, mostly part of carsharing members, as it has been observed previously, relinquish the purchase of private vehicles by 34.4%, but this report also wonder itself about the decision or change of pattern experienced by the rest of carsharing users. This is to say, user modal shift after knowing carsharing services resulted to be as following shares, which higher weights reaffirm the previous statements of automobile holdings, but these results also show behavioural shift to widespread purchase of other modes such as motorcycle and bicycles by 2.5% and 8.8% respectively.

Figure 28 Users mobility patterns due to carsharing membership



Source 28 Authors' own. Data: Enquête Nationale Autopartage 6T-Bureau de recherche

E.2.2. Decline of vehicle kilometres travelled (VKT) caused by carsharing usage

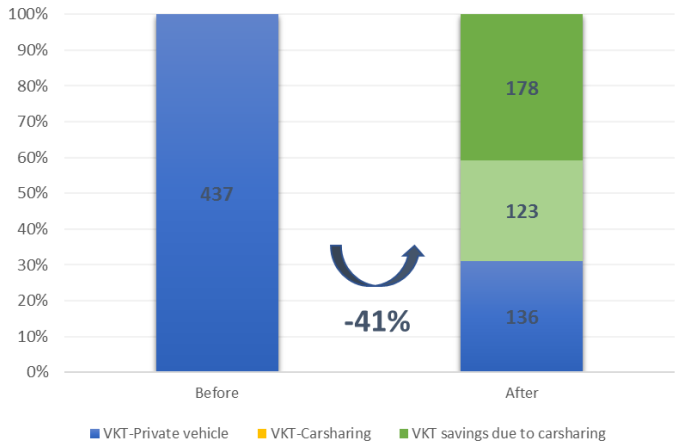
Furthermore, since carsharing services drive a considerable reduction on vehicle ownership, the accessibility is improved, and hence, private vehicle distance also declines. In other words, carsharing not only impacts on private ownership, it even reacts on the reduction of unoccupied public space and travelled distance

Europe countries found out a large decrease in vehicle travelled distance by 28% to 45%. In contrast, VKT range among North America, including Canada as well as United States, resulted to be highly wider, 7.8% to 80%. [53]

According to Autolib' experience and the Agence de l'Environment et de la Maîtrise de l'Energie, VKT study is deeper developed by means of before-after analysis, which provides to this research more accurate data that will supports the study. So, French carsharing system figured out the following VKT evolution:

[53] ITS UC Davis, Worldwide Carsharing Growth: An International Comparison

Figure 29 Before-after analysis of vehicle kilometres travelled (VKT)



Source 29 Authors' own. Data: Enquête Nationale Autopartage 6T-Bureau de recherche

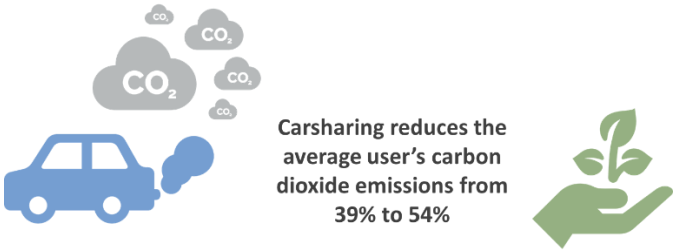
Therefore, the exhibit above represents a decline of VKT by 41%, which meet the range mentioned previously (28% to 45%). In addition, the evolution of VKT' adjustment outcomes a reduction by 178 kilometres; Figure 29. Thus, after joining a carsharing service commuters clearly shift their mobility patterns to shorter distances, which has a direct impact to the reduction of greenhouse gas emissions (GHG).

Also, several sources show up that carsharing membership exhibits a decline of VKT with the pass of the years. In other words, once commuters join shared mobility, they experience an increase of the average VKT' saving over years as they are easily able to sell or break free from automobilism.

E.2.3. Eco-friendly user patterns and sustainable mobility because of carsharing introduction

Many reasons resulted to be improving the environmental effects of mobility, which is currently one of the most challenges that climate change wants to fight. Hence, previous results such as the decline in fuel-consumption vehicle kilometres travelled and the raising tendency of non-ownership, both contribute significantly to the reduction of greenhouse gas emissions.

Among European countries, there are many studies which suggest that each citizen joining carsharing services reduces the average user's carbon dioxide emissions from 39 to 54 %. Nevertheless, this environmental improvement is not only due to non-ownership and VKT decline as many carsharing operators are willing to introduce sustainable fleets to commit even further to fight against climate change.



In addition, carsharing users also report a higher degree of environmental awareness after joining these services, so that low-emission sharing mobility fleets lead to a reduction of about 200-290 kilograms of CO2 emissions per year per active user.[54]

[54] Car-Sharing – "Car-on-call" for reclaiming street space. MichaelGlotz-Richter, 2012.

E.3. Case Studies - Shifting users' behaviour among different transport modes

In order to figure out the economic effects of carsharing, and so to evaluate the change of investment indicators among different transport modes due to the implementation of carsharing services, this report proceeds to study the modifications of travel behaviour with respect to different modes. Therefore, this chapter aims to understand the transport modal shift as a result of carsharing. Meanwhile, behavioural shift analysis slightly diverges between different cities since each urban planning, population density and user behaviours in cities is unique, and hence, the modal shift will also play out distinctly. For this reason, the report evaluates three analyses for different population density magnitudes and user patterns.

With this aim in mind, some considerations should be highlighted related to gathered data in order to gain a better grasp of the analysis. Thus, this study, even though carsharing differed one from each other - round trip, one-way, peer-to-peer and fractional – it is based on one-way carsharing service provider with a free-floating operational model. At the same time, scientific observed data was extracted from active members within each city.

E.3.1. Canadian Cities – Vancouver and Calgary (Car2Go)

Many times, Vancouver has been identified as the capital of car share all around the world as it reaches the highest number of car share per habitant, embracing over 65,000 members and close to 1,000 car share vehicles[55]. Furthermore, Vancouver is positioned as remarkable car share matured network, in essence related to the membership observed in each city and its fleet size.

On the other hand, Calgary shrinks to 73 square kilometres over 114 effectives[56], embracing centralized geographical model to address shortages in the downtown core. At the same time, in low demand areas carsharing services were not easily accessible

[55] Ca2Go, Modo and Zipcar
[56] Car2Go car sharing service cuts Calgary service area

for the user, seeking for the continuous ridership and for the minimization of occupying fixed space.

Whereas Vancouver exhibits a larger member population and fleets in car share platforms, the largest overall impact on a per vehicle basis driven by its large suppression effect is observed in Calgary. Furthermore, the vehicle impacts vary by city, not only because of the fleet size. What is more, Calgary shows a within-city range of vehicles removed per each car share 2 to 11, but Vancouver 2 to 9 (E.Martin and S. Shaheen, 2016). On average, private vehicles were shed per car share vehicles among all studied cities.

Nevertheless, vehicle impact as a result of carsharing services should not only consider the replacement rate among active members, the aggregate impacts reported by each city are a function of the active population using the system, the fleet size and how users answered travel behaviour. According to aggregate impacts, Vancouver as high-density city exhibit a larger aggregate impact, considering the replacing rate in terms of personal vehicles. In other words, other decision variables play a contribute role such as the amount of car share vehicles within walking distance from home or the ratio of household vehicle holdings.

Therefore, this report studies the transport modal shift as a result of car share in Vancouver and Calgary, in order to gain perspective whether car share is a replacing or complement disruptive mode to other active transport modes. In particular, how do commuters use public transportation; specifically, bus, urban rail and intercity rail. Besides, the modal shift analysis detailed below also considers the changes on non-motorized modes such as walking and bicycling (Figure 30 and Figure 31).

According to Scenario 2 theoretically designed at chapter D.6.2.I, while private vehicles experience a decline in number of personal vehicles but not in users, public transit users also are persuaded to shift their modal choice in favour to car share. In efforts to understand Vancouver switching behaviour, this report complements the analysis by the theoretical scenario which allow to gain in-depth perspective of Vancouver' impacts. Vancouver shows an increase in the overall drive, which agree with the growing tendency to relinquish automobilism ownership as well as the increasing number of drivers including both private vehicles and car share.

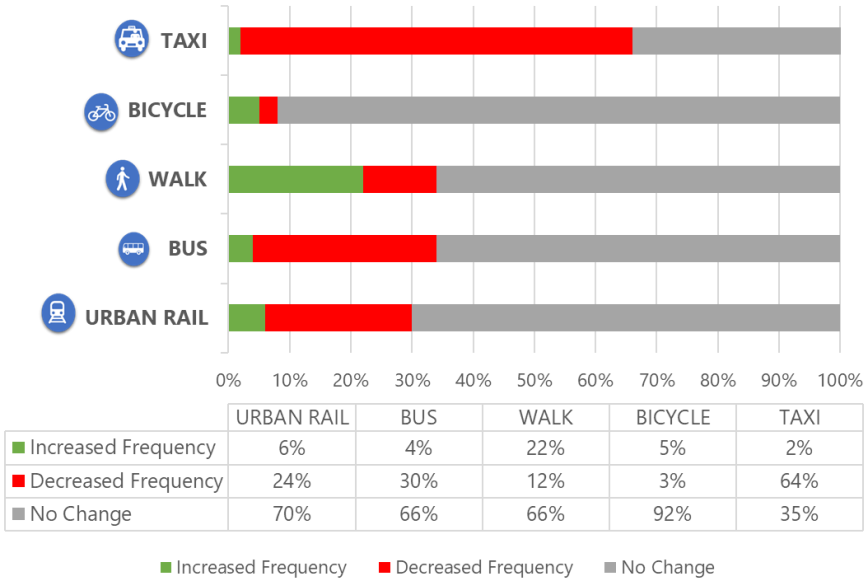
Therefore;

$$N_{VP}^{before\ carsharing} > N_{VP}^{after\ carsharing}\ (-\%VP, -64\%Taxi\ and + \%\ carshare) \quad (17)$$

$$N_{TP-Vancouver}^{before\ carsharing} > N_{TP(bus)-Vancouver}^{after\ carsharing}\ (-30\%) + N_{TP(urban\ rail)-Vancouver}^{after\ carsharing}\ (-24\%) \quad (18)$$

$$\Delta N_x = N_w^{after\ carsharing}(+22\%) + N_b^{after\ carsharing}(+5\%) + \%\ carshare + \cdots + N_x \quad (19)$$

Figure 30 Carsharing effects on modal shift (Calgary, United States with lower population density of 3,400 people per sq.mile)



	URBAN RAIL	BUS	WALK	BICYCLE	TAXI
Increased Frequency	6%	4%	22%	5%	2%
Decreased Frequency	24%	30%	12%	3%	64%
No Change	70%	66%	66%	92%	35%

Source 30 Authors' own Elaboration. Data: Impacts of Car2Go on Vehicle Ownership, Modal Shift and Vehicle Miles Traveled, and Greenhouse Gas emissions: An Analysis of five North American Cities

Once again, the same theoretical Scenario 2; D.6.2.I, is perceived in Calgary transport modal shift as car ownership as well as public transit usage decline. On contrast to Vancouver, alternatives within public transit are affected differently although the whole public transit share also decreases as a whole.

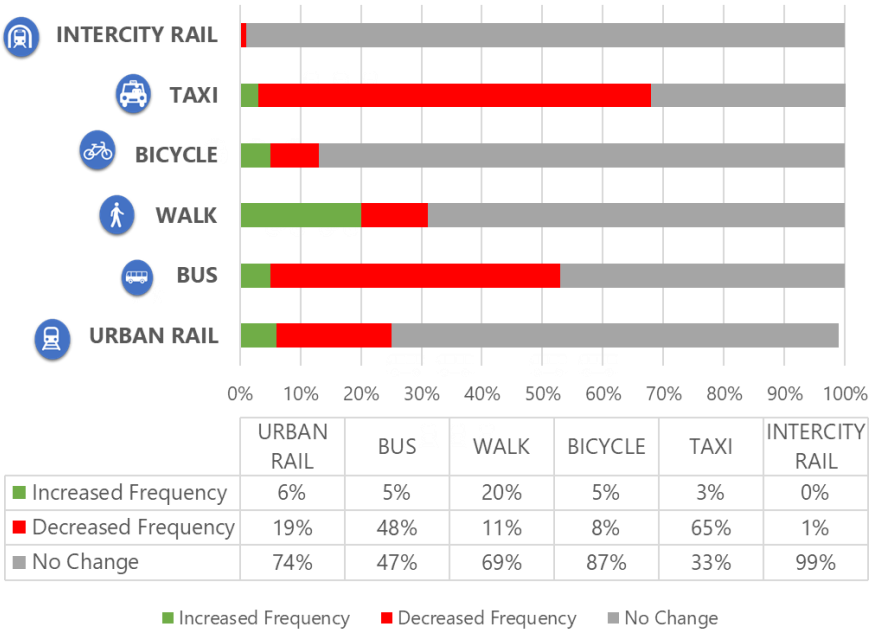
Furthermore,

$$N_{VP}^{before\ carsharing} > N_{VP}^{after\ carsharing}\ (-\%VP, -65\%Taxi\ and + \%\ carshare) \quad (20)$$

$$N_{TP-Vancouver}^{before\ carsharing} > N_{TP(bus)-Vancouver}^{after\ carsharing}\ (-48\%) + N_{TP(urban\ rail)-Vancouver}^{after\ carsharing}\ (-19\%) \quad (21)$$

$$\Delta N_x = N_w^{after\ carsharing}(+20\%) + N_b^{after\ carsharing}(+5\%) + \%\ carshare + \cdots + N_x \quad (22)$$

Figure 31 Carsharing effects on modal shift. (Vancouver, Canada with higher population density of 13,000 people per sq.mile)



	URBAN RAIL	BUS	WALK	BICYCLE	TAXI	INTERCITY RAIL
Increased Frequency	6%	5%	20%	5%	3%	0%
Decreased Frequency	19%	48%	11%	8%	65%	1%
No Change	74%	47%	69%	87%	33%	99%

Source 31 Authors' own Elaboration. Data: Impacts of Car2Go on Vehicle Ownership, Modal Shift and Vehicle Miles Traveled, and Greenhouse Gas emissions: An Analysis of five North American Cities

Regarding the transport modal shift comparatively among different Canadian cities – Vancouver and Calgary – a majority of members exhibit no change in public transportation use due to carsharing services. But among those that do change their behaviour, the count of carsharing reducing their public transit use outnumbers the count of those increasing their use.

Although Calgary and Vancouver show quite similarities in their modal shit effects among public transit, bus usage experiences a more prominent decline in Vancouver (-48% versus -30%), what puts forward that the urban planning and other mobility externalities influence differently to users' patterns. In Vancouver the fleet size and the accessibility to car share from residence is higher than Calgary, what the value of time door-to-door is reduced by the deployment of carsharing. In addition, Calgary centric-based model versus Vancouver spread service willing to cover suburban areas where transit remain shorter than metropolitan area, exhibit that bus network is reshaped by means of

carsharing emergence in high-coverage service in Vancouver. Thus, Vancouver shows an intention of larger transportation network complement transit and other modes.

All in all, some of the highlights from Canadian analyses are that public transportation usage experience a clear decline, in which bus as well as urban rail realised a remarkably reduction because of carsharing, surpassing even more in higher population density and larger fleet size, Vancouver. While high-density cities have a largest percentage of active members, lower-density territories exhibit lower active users relative to their respective membership base.

All these findings lead to the statement that city attributes, such as population density, public transportation access and vehicles per households also play a contributing role to how each population responses to the presence of carsharing. In total, carsharing effect distinctively on public transportation as a function of total membership size, total fleet size, the rate of private vehicle sold and suppressed, the percentage of active members in each city and the frequency distribution of vehicles.

In addition, among those that do change their behaviour intensely, both cities exhibit a significant alteration in taxi demand rate, that diminishes hugely by 64-65%, which certainly is motivated by variables such as comfort, flexibility as well as pricing that are for the sake of carsharing. As Calgary and Vancouver carsharing model is more centre-based, the ancient taxis displacements within-city are considerable shifted to car sharing. Plus, travelled-distance, as reported before, is another decision variable that by the implementation of carsharing exhibits a clear determination for new innovative models instead of taxis use.

E.3.2.French cities and territories

I. Ile de France – Metropolitan area (Autolib' and Mobizen)

As each city works distinctively and also socio-political frameworks define the effect of car share, this report delves into other examples in the Ile de France. At the first stage, Ile de France exhibits a clear replacement of private vehicle as a result of shared mobility emergence, reaching diverged results among car share operators; Autolib' and Mobizen.

Figure 32 Private vehicle effects driven by car share implementation in Ile de France, Paris

Source 32 Enquête sur l'impact d'un service d'autopartage en trace directe (le cas Autolib' et le cas Mobizen)

Furthermore, Ile de France exhibits a remarkable impact on other modes of transportation. One the one side, Autolib' resulted to the detrimental to public transit in the metropolitan area, attracting public transportation travellers onto shared mobility. Paris public transportation network is one of the most well-known all across the globe, and as Autolib' is usually perceived as a useful mode to commute within city, it results understandable that portion of public transit users have been kept by car share.

On the other side, on contrast, over the same territorial boundaries – Ile de France – another carsharing operator, Mobizen, shifts the behaviour of public transit advantageously, reaching a slightly increase in its demand. This puts forward that, according to carsharing operator, its fleet size, distribution of pods and its strategical location defines completely if carshare will be complement or substitute of public transit within each city.

As the theoretical model reported at chapter D.6.2, Ile de France behavioural shift result in a variation of public transportation demand, both upward and downward depending on carsharing network operator; Autolib' or Mobizen, which leads this report to still state the fact that public transit alters its share of demand according to further contributing variables into the equation.

On contrast to Vancouver, disparate alternatives within public transit are affected differently although the whole public transit share also decreases as a whole.

Consequently;

$$N_{VP-IdF}^{before\ carsharing} > N_{VP-IdF(Mobizen)}^{after\ carsharing}\ (-93\%VP)\ and\ N_{VP-IdF\ (Autolib)}^{after\ carsharing}\ (-63\%VP) \quad (23)$$

In accordance to a substitute alternative mode to public transit, Autolib carsharing concludes;

$$N_{TP-IdF}^{before\ carsharing} > N_{TP-IdF\ (Autolib)}^{after\ carsharing}(-18\%) \quad (24)$$

On the other side, contrarily, Mobizen carsharing results as a complementary transport modal choice to public transit;

$$N_{TP-IdF}^{before\ carsharing} < N_{TP-IdF\ (Mobizen)}^{after\ carsharing}(+2\%) \quad (25)$$

Still, both carsharing within the Ile de France affects distinctively to healthy habitudes such as an increase in walkability. Whereas Mobizen, which resulted advantageous to public transit, also promote walkability in the city, Autolib, which concluded a detrimental contributing to public transit, still decreases walking share.

Furthermore,

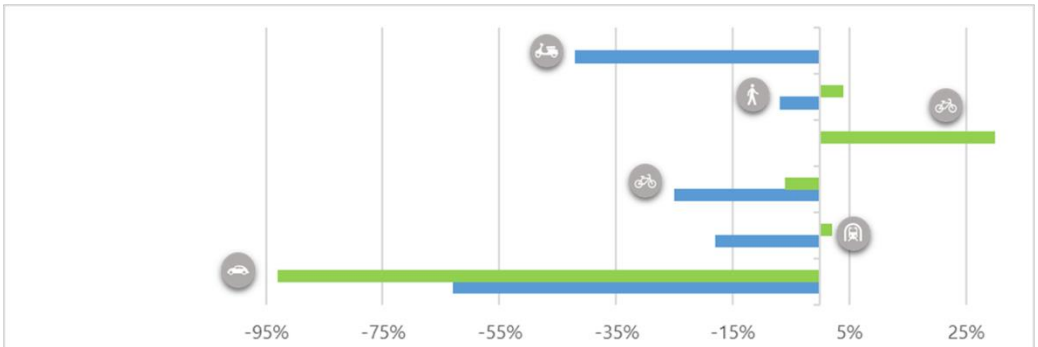
$$\Delta N_{x-IdF\ (Mobizen)} = N_{w-IdF\ (Mobizen)}^{after\ carsharing}(+4\%) + N_{b-share\ IdF(Mobizen)}^{after\ carsharing}(+30\%) + \cdots + N_x \quad (26)$$

whereas,

$$\Delta N_{x-IdF\ (Autolib)} = N_{w-IdF\ (Autolib)}^{after\ carsharing}(-7\%) + N_{bicycle-share(Autolib)}^{after\ carsharing}(0\%) + \cdots + N_x \quad (27)$$

Not to mention that Ile de France in Paris, deployed one of the most recognized bicycle share networks and it results a positive increase because of Mobizen' car share rather than Autolib', which leads this report to believe that Mobizen pods are strategically well-distributed among public transit stations and bicycle share system pods in order to complement other alternatives of transport favourably.

Figure 33 Carsharing effects on modal shift. (Autolib' and Mobizen, Ile de France)



	PRIVATE VEHICLES	PUBLIC TRANSPORTATION	BICYCLE	BICYCLE SHARE	WALK	MOTORIZED TWO-WHEELED VEHICLES
ILE DE FRANCE-MOBIZEN	-93%	2%	-6%	30%	4%	0%
ILE DE FRANCE -AUTOLIB'	-63%	-18%	-25%	0%	-7%	-42%

Source 33 Authors' own Elaboration. Data: Enquête Nationale Autopartage 6T-Bureau de recherche.

II. Out of Ile de France – Interconnections of interurban and urban transport

In efforts to gain understanding of public transit demand due to carshare, Paris is even more analysed below. The Figure 34 still considers French territory, but out of Ile de France as both Mobizen and Autolib' operated out of the metropolitan centre. In this case, car share impacts advantageously to the public transit use, reason why this report notes that the territorial scope of the operating service is also determinant to their effects. Nevertheless, the benefits of car share in lower density areas are unlikely to deliver more return in investment in short term, but it reshapes the intensification of established public transit corridors thriving carsharing as a complement to transit, rather than a substitute. Furthermore, carshare as adjoining enabler between urban and interurban areas could play a supporting role for public transportation in effort to improve its share of use and to attract travel behaviours facing disruptive and innovative mobility modes. All in all, interurban and urban joint is another find open to further discussion while implementing carsharing.

With this in mind, interurban travel behaviour and the interconnection to urban areas respond to the scenario 3 reported at chapter D.6.2.II, in which public transit results benefited as a result of car share implementation as a complementary mode of mobility to access easily to urban areas.

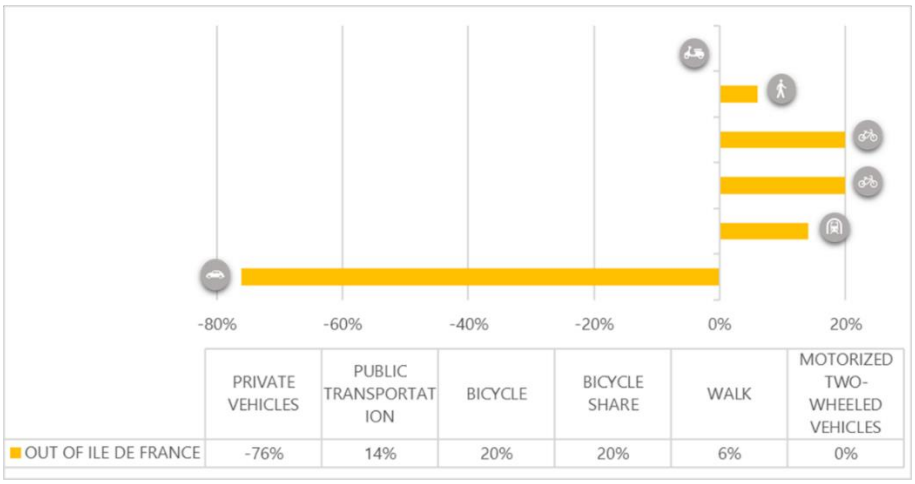
As a result;

$$N_{VP-OutIdF}^{before\ carsharing} > N_{VP-OutIdF}^{after\ carsharing}\ (-76\%VP) \quad (28)$$

$$N_{TP-OutIdF}^{before\ carsharing} < N_{TP-OutIdF}^{after\ carsharing}(+14\%) \quad (29)$$

$$\Delta N_{x-OutIdF} = N_{w-OutIdF}^{after\ carsharing}(+6\%) + N_{bicycle-OutIdF}^{after\ carsharing}(+20\%) + \cdots + N_x \quad (30)$$

Figure 34 Carsharing effects on modal shift. (Out of Ile de France)



	PRIVATE VEHICLES	PUBLIC TRANSPORTATION	BICYCLE	BICYCLE SHARE	WALK	MOTORIZED TWO-WHEELED VEHICLES
OUT OF ILE DE FRANCE	-76%	14%	20%	20%	6%	0%

Source 34 Authors' own Elaboration. Data: Enquête Nationale Autopartage 6T-Bureau de recherche.

III. France – Carshare territorial network

European countries such as France determine a significant increase of walking as a quotidian mode of mobility by 31 %, consecutively bicycle by 30% and then public transportation and train both by 25%. These results conclude an important shifting of user behaviour driven by carsharing services implementation and awareness. Also, the diminish of automobile usage is an evidence according to previous case studies. In particular, French analysis agrees the statement as carsharing exhibits a decrease of private vehicles by 9% and a decline of taxi use by 13%.

A wider geographical scope to analyse the travel behaviour corresponds to the switching behaviour reported at chapter D.6.2.II, although in this case all effects are more prominently perceived as a result of car share implementation among the whole French

country. At the same time, France also concludes a relinquish of automobilism for the sake of carsharing, but it suggests a lesser significant impact compared to all previous real cases. In other words, expanding the focus of analysis also alters the transversal impacts of carshare heterogeneously.

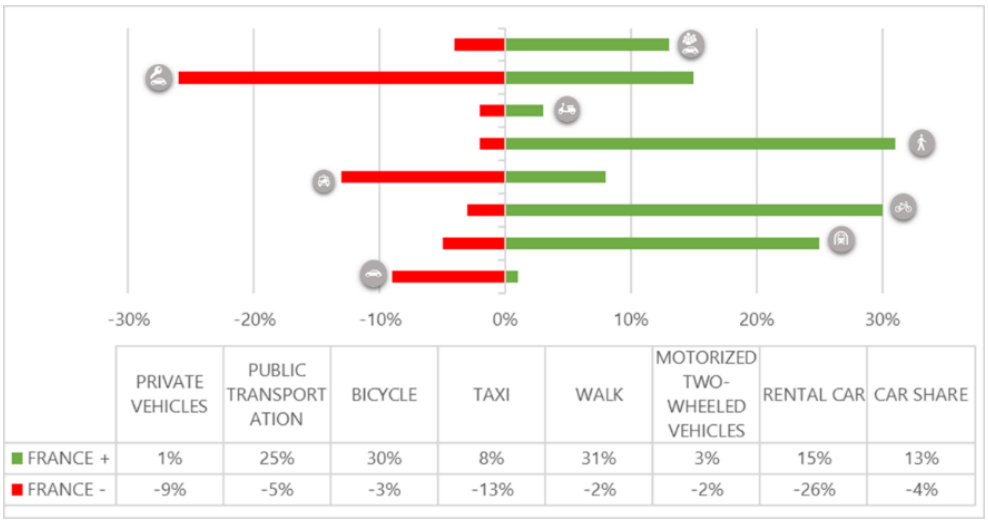
Furthermore;

$$N_{VP-France}^{before\ carsharing} > N_{VP-France}^{after\ carsharing}\ (-9\%VP) \tag{31}$$

$$N_{TP-France}^{before\ carsharing} \ll N_{TP-France}^{after\ carsharing}(+25\%) \tag{32}$$

$$\Delta N_{x-France} = N_{w-France}^{after\ carsharing}(+31\%) + N_{bicycle-France}^{after\ carsharing}(+30\%) + \cdots + N_x \tag{33}$$

Figure 35 Carsharing effects on modal shift. (France - Country)

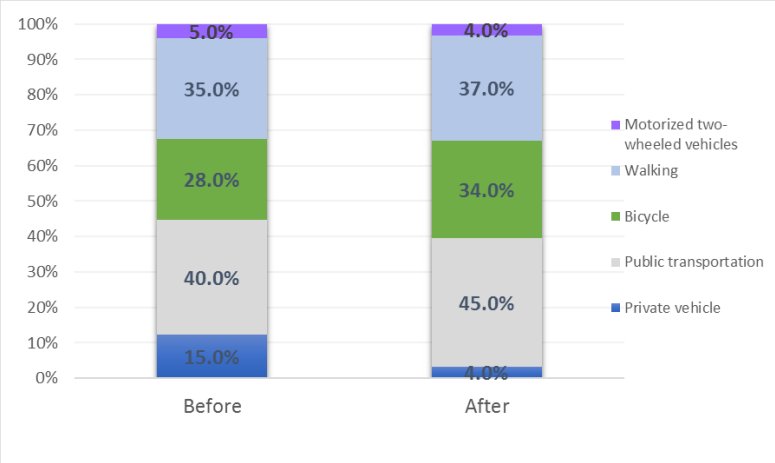


	PRIVATE VEHICLES	PUBLIC TRANSPORTATION	BICYCLE	TAXI	WALK	MOTORIZED TWO-WHEELED VEHICLES	RENTAL CAR	CAR SHARE
FRANCE +	1%	25%	30%	8%	31%	3%	15%	13%
FRANCE -	-9%	-5%	-3%	-13%	-2%	-2%	-26%	-4%

Source 35Authors' own Elaboration. Data: Enquête Nationale Autopartage 6T-Bureau de recherche.

Moreover, these studies are complemented with a before-after analysis through which this report will be able to analyse the economical variance due to the fact that the introduction of carsharing services causes a clear shift on users' patterns among different modes of transport.

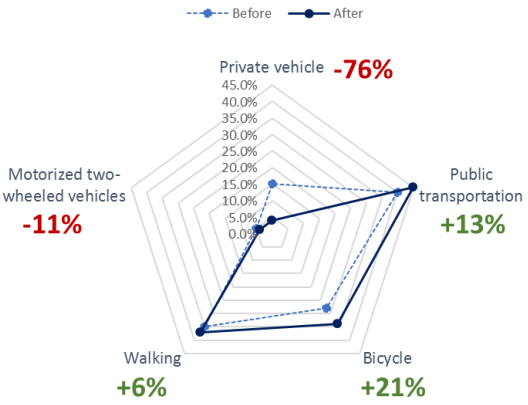
Figure 36 Before-after transport modes usage motivated by carsharing implementation



Source 36 Authors' own Elaboration. Data: Enquête Nationale Autopartage 6T-Bureau de recherche.

In other words, the evolution of those modes of transport resulted to drop both private vehicles and motorized two-wheeled vehicles, and widespread the use of public transportation, bicycle and walking successively.

Figure 37 Evolution of different transport modes usage inducted to carsharing



Source 37 Authors' own Elaboration. Data: Enquête Nationale Autopartage 6T-Bureau de recherche.

Conclusively, as there are many variables that determine the behavioural shift of public transit, some of the parameters that France perceives a considerable prominence of carshare to result complement to public transit are determinant variables of the transport modal choice approximate function; $f(N_{TP-France}^{before\ carsharing})$:

$$N_{TP-France}^{after\ carsharing} = f(N_{TP-France}^{before\ carsharing}(F, T, M, I_{\alpha}, G_{s}, \dots)) \quad (34)$$

Where;

F; frequency of carsharing usage which increase proportionally the effects of its implementation

T; travelled distance

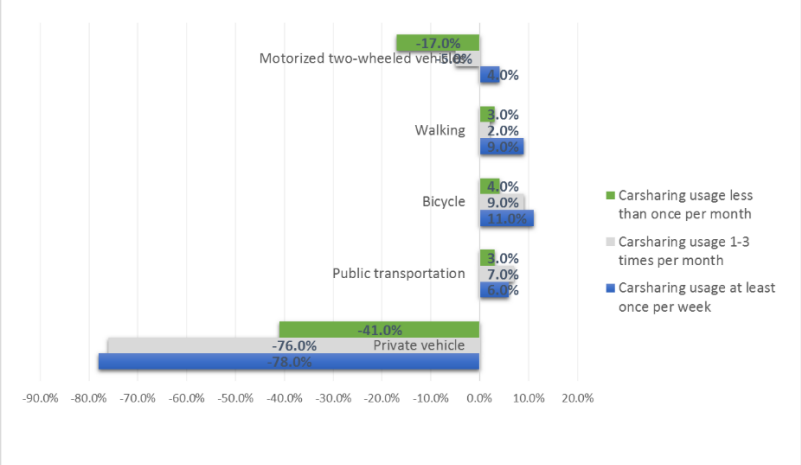
M; carshare fleet size

I_α; intermodality or multimodal integration system rate between carshare pods and public transit stations

G_s; geographical scope of analysis

All in all, the frequency of carsharing usage also plays an important role in transport modal shift as observed at Figure 38, where public transportation shift becomes more prominent for high-frequency carsharing members. In other words, this puts evidence that once commuters decide to join carsharing services and they find them convenient to their common displacements, they get used to flexibility and comfort so that they tend to adopt alternative mobility occasionally rather than using public transportation.

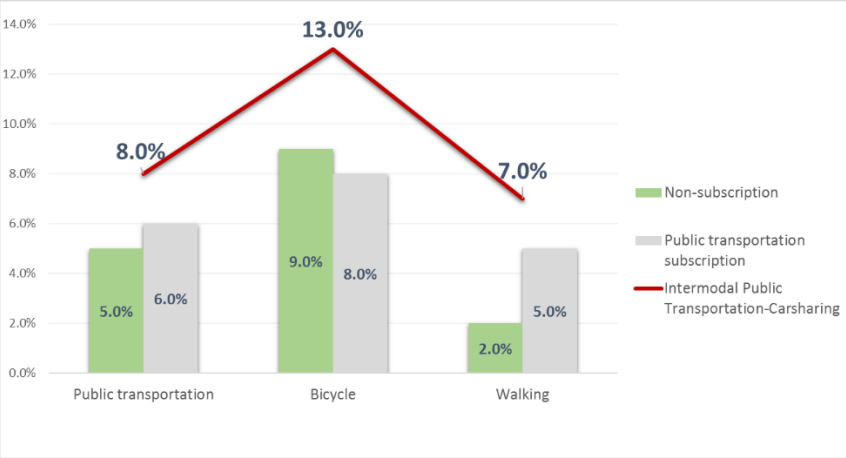
Figure 38 Transport modal shift due to carsharing frequency usage



Source 38 Authors' own Elaboration. Data: Enquête Nationale Autopartage 6T-Bureau de recherche.

Therefore, frequency agile transport modal shift, raising the usage of non-motorized modes of transport (eg. walking, bicycle and public transportation) and notable declining private vehicle use. However, motorized two-wheeled vehicles are the unique alternative of transport that completely change their tendency of transport modal shift with the growth of carsharing usage (-17% to +4%).

Figure 39 Transport modal shift motivated by TP-carsharing intermodality



Source 39 Authors' own Elaboration. Data: Enquête Nationale Autopartage 6T-Bureau de recherche.

In sum, as observed at Figure 39, integration of multimodality and so the easiness of transhipment between different modes of transportation inducts an increase of alternative sustainable mobility modes such as public transportation, bicycle, and walking. These results expose not only that using more than one mode of transport is growing substantially, but also that multimodality and intermodality easiness by means of integrated ticketing system and pricing customization are fundamental determinants to raise public transportation adoption, reaching a higher 8% compared to inexistent intermodality or integrated subscription system; Figure 39. Overall, technologies and new transport system features are also determining in modal shift and users' patterns.

Many transport experts come up with the insight that smart ticketing including features such as an integrated payment system will revolutionize transport modal choice, and also will be an opportunity to the future of public transportation. Additionally, engaging customer by becoming a conduit for real-time information could be a further step in the future of mobility. All told, integrated multimodality mostly influences on bicycle usage, which means that the integration strategies propitious healthy, sustainable and flexible modes as bicycle.

E.4. Insights from shifting user patterns

E.4.1.Key findings

Considering previous modal shift analyses, it can be highlighted some insights due to carsharing implementation:

I. Carsharing inducts a decrease rather than an increase of public transportation.

Those three cities figured out that carsharing have not substantively shift their behaviour of public transportation mode. Overall, in Calgary and Vancouver cases, more urbanites decrease rather than increase their public transit use as a consequence of shared mobility. On the contrary, France shows a raising tendency of public transportation share. It makes sense to figure out different results on transport modal shift between different cities and population densities, but even more significant between different continents, where habitudes, urban space and distribution, alternatives build completely distinctive mobility patterns. As long as this report concerns, French cities have developed a more developed maturity model and the range of transport alternatives it offers is quite different from North American cities.

Furthermore, as shared mobility seems to have mixed impacts on public transportation use, frequency of carsharing services seem to have prominent effects to increase public transportation usage. In other words, those users who use carsharing services more frequently tend to use multimodality in their journey, and hence these users are more susceptible to shift their mobility patterns adopting alternative modes such as public transportation. Nevertheless, carsharing does not conclude as direct competitor to public transportation.

Also, pricing is not a determining factor to invite public transportation users to use more carsharing instead.

In addition, there is a considerable decrease on urban rail, an even higher in cities with lower population densities such as Vancouver as business district area. Besides, commuters significantly decrease their use of bus network because of the

availability of carsharing services. For highly populated cities, the reduction of bus use is still prominent.

As carsharing impacts on public transportation are mixed, there are other variables that would be further analysed to understand this transport behavioural shit.

II. Combining modes of transport invites more users to carsharing and increase public transport usage

Seeing that carsharing impacts differently on public transportation use, it should be reflected upon the convenience of combining both possibilities depending on the shape and interconnectivity of different cities. Across the densely populated cities, the accessibility from suburbs or surroundings into metropolitan areas commonly represent one of the biggest challenges of transportation networks around the world so that these cities conclude some more relevant impacts due to carsharing services.

Consequently, this report questions the fact that the integration between carsharing and public transportation generates a rising use of urban rail as well as subway in these densely areas.

Moreover, the flexibility of carsharing services invites more active members. However, as these services operate according to pay-as-you-drive principle, they raise the awareness of individual travel costs. Thus, commuters change their travel patterns and so carsharing lead them to adopt sustainable and cheaper modes such as public transportation.

In other words, pay-as-you-drive principle induces shift of users' behaviour embracing more transhipment, and hence combining different transport modes; carsharing and public transportation.

Related to the tendency of commuters using transportation multimodality because of the increase of modal alternatives in the territory, there have seen that the integrated multimodality and so combination between public transportation and carsharing causes an increase of public transportation usage, as well as other non-motorized modes of mobility such as bicycle and walking.

III. Longer-distance public transportation do not have substantial alterations as a result of carsharing

Other public transportation modes such as intercity rail in cities resulted very small. These sort of travel modes are significantly used by longer distance travels. As it has been seen before in transportation modes balance matrix, for long-distances cater car-pooling, rental car and public transportation.

Apart from long-distance influence factor to adopt these modes, the remaining percentage without change their behaviour is also because carsharing services have a limited and boundered operating areas, still not spread into the whole territory.

Another insight concluded from this analysis is that strengthening both public and private partnerships between public transportation operators and municipalities could be determining to widespread use public transportation, for instance, by means of installing station-based carsharing at public transportation main stations. These initiatives allow the conductive of combining both public transport and carsharing services for whom they travel long-distance by intercity rail.

IV. Carsharing high frequency usage and multimodality increase sustainable mobility modes such as bicycle and walking

Many results of transport modal shift analysis evidence that multimodality inducts an increase of bicycle and walking as mode of mobility in urban areas. This puts forward not only that with the pass of the years commuters are significantly thinking about mobility as a service rather than transportation, it also shows that future mobility modes such as carsharing are reshaping the way that users perceive mobility as they tend to prefer multimodality rather than comfort and expensive private vehicles. Furthermore, bicycle and waking experience a considerable increase, which additionally means that shared mobility invites further sustainable mobility.

In addition, bicycle is obtaining an increase that resulted from carsharing services. Nevertheless, specially, personal bike suggests a higher increase rather than public bike sharing. (Shaheen, Susan, Martin, Elliot and Bansal, Apaar, 2018)

V. Corporate carsharing services catch portion of public transportation users

This report also showed that business carsharing services are growing as employees think it as an effective, competitive, flexible, on-demand, well balanced pricing mode of transport. Many companies suggest these services as an appeal to explore alternatives instead of bringing one car per person at work.[57] Among Catalan territory, many companies are starting to launch AppBus' quizzes to their employees in order to know their journeys, timetables and patterns and search for an optimal bus network route through the closes pick-up points for the whole company. Therefore, these new shapes of mobility appeal commuters to change their patterns, and so catching an amount of public transportation customers. Although the observed impacts of corporate carsharing services is that they do not reduce public transportation share, they do observe that many commuters use public transportation more often than before.

Furthermore, many corporate carsharing figured out that if they were not available, an 18% would have taken public transportation instead.[58]

E.4.2. Understanding mobility users' patterns: Categorization of modal choice and potentiality to adopt carsharing services

After analysing carsharing customer profiles and transport modal shift, this report explores upon the possible reasons that induct users to their modal choice. Doing so, this section aims to categorize mobility patterns and select those whom subscribe carsharing usage.

Faithful customer of private vehicle: They are traditional customer of private vehicle who are used to take advantage of comfort and their choice is unconditionally automobile usage, no mattering the inconveniences to get to their destiny. With this aim in mind, these users are distinctive socioeconomic that can afford such time and cost losses as seen by private vehicles. In addition, these customers do not envisage any other mode

[57] Adam Millard-Ball. Car-Sharing: Where and How It Succeeds. 2005
[58] Susan Shaheen and Adam Stocker. Zipcar Case Study & Impact Analysis. Transportation Sustainability Research Center - University of California, Berkeley. July 2015

of transport, at least, that offers the same advantages as private vehicle so that their perception of public transportation is bad.

Although municipalities and political regulations are increasingly adopting regulations that will ban private vehicles circulation within cities and they are gradually reducing petrol and diesel combustion engines by means of restrictive regulations, this sort of customers are faithful to automobilism. According to data analysed previously in transport modal shift, these customers represent the 22% that resist to alternative mobility offers and persist owning private vehicles. (4% persist having more than two-wheeled vehicles and 18% having one vehicle). Furthermore, these users do no tend to become carsharing membership in short term.

Open-minded private vehicle' use: They are commonly private vehicle users that are open-minded to adopt new mobility modes according to their convenience. In addition, they do not have prejudices about public transportation usage. These customers are used to automobilism' advantages and if they have given up this mode of transport, it would be instead of much more competitive mobility service. Nowadays these users do not seem to be attracted by carsharing services, as they perceive them as newly, youthy and inflexible mobility compared to private automobile. Nevertheless, the raising of political, social and cultural frameworks could shift open-minded modal choices to potential new members of carsharing. Some of the reasons that could play a strategic inclusion of them in carsharing services are pricing effectiveness and VKT reduction.

Reluctant to private vehicle' use: They are travellers who are not appealed by private vehicle at all, so that they envisage their modal choice according to public transportation, bicycle and walking offering. These users remain in the original 39% of automobile non-ownership or in the initial 87.7% of motorized two-wheeled non-ownership, as they conviction say themselves since the origin that they do not use motorized vehicles. With this statement, this report concludes that this category of users does not change their mobility behaviour as a result of carsharing services.

Within this category of users, there are ecologist and eco-friendly convictions even though they do not adopt carsharing services because of their environmental commitment.

Cheaper itinerary preferences: To whom pricing is the prior decision variable to make their modal choice, carsharing does not enter to their envisaged alternatives because of pricing competitiveness of public transportation, walking and bicycle.

Therefore, as reported previously, carsharing mostly users hold a distinctive socio-economic profile, which also supports the previous statement.

Preference to private vehicle' use, though externalities lead them to take other modes of mobility: There are also people who prefer to use private vehicles whereas there are many externalities that lead them to use another transport modes. In other words, the agglomeration in cities is making even more difficult to get parking in urban areas which means that not only the time to get it increases, the cost of fuel and VKT also rises.

Environmental and pedestrian strategies make even difficult the use of private vehicles, and so gathering mobility alternatives pushes commuters to explore new ways of transportation such as public transportation, bicycle and walking.

Additionally, climate change consciousness becomes another factor to shift their modal choice, adopting more sustainable and green mobility modes.

All told, these customers become potential opportunities to adopt carsharing services. According to data reported previously, 31.5% decide shedding vehicle because of carsharing offering, so these customers would be included in this modal shift as they make their modal choice according to a different transport alternatives balance and their conditions of wellness such as on-demand pricing and the no need to get place to park.

In accordance with Calgary, Vancouver and Paris case studies, these users are part of the users within the decrease of private vehicle use and the increase in walking. Thus, as these modes are not easily or directly converted one from each other, these customers, who decide to not own a private automobile any more, tend to adopt multimodality combining carsharing with walking. All modal shit analyses reported show a notable increase in walking due to carsharing services.

Preference to public transportation, bicycle and walking use because of their mobility characteristics: These commuters prefer public transportation, bicycle and walking because of their features and advantages such as non-ownership of private vehicle fixed costs and fuel consumption, so that they are not carsharing main profile.

Shortest itinerary preferences: Those whom make their modal choice as a result of a balance of the distance to be travelled and the associated alternatives seem to become more similar to carsharing users' patterns as they envisage mobility as a service, without analysing transport modes but having into account the itinerary advantages as a whole. Furthermore, these users are the most unpredictable as they do not choice their transport

mode according to each alternative but according to the shortest itinerary so that the value of time of these customers are the highest as it becomes their principle variable decision.

Additionally, globalization and congestion challenges are putting private vehicles in an unattractive position for those customers who seek for speediness. With this in mind, although the distance to be travelled in roads is commonly shorter than public transportation in terms of kilometres, many growing externalities such as congestion and restrictive policies position other alternatives preferred for these customers.

Furthermore, depending on urban distribution of the city and its accessibility to go walking from one point to another determine the raising tendency of walking and bicycle versus public transportation. However, the length to be travelled clearly indicates the modal choice between different non-motorized modes of transport when user' priority is time savings.

Closeness to mobility offering: As observed in this report, living far from your daily destiny as well as being part of a dense urban area multifunctional become determinants to adopt carsharing services. Furthermore, who envisage closeness as their priority in their modal choice do not usually consider motorized modes as an option for their mobility, even though they could be occasional customers of shared mobility as part of their multimodality path. Thus, acquiring more active carsharing members can also be leveraged by providing integrated multimodality with public transportation.

Additionally, the modal choice of these users can be influenced considerably depending on carsharing fleet size and spread within cities. The operating area and the dispersion rate of carsharing service invite further commuters to adopt these disruptive and innovative mobility modes.

F. FINANCING EFFECTS OF SHIFTING USERS' BEHAVIOUR

F.1. Carsharing' case studies analysis

F.1.1. Canadian study cases: Calgary and Vancouver

Calgary as well as Vancouver experimented a significant decrease in urban rail and bus network users demand and furthermore average costs of users and public transportation operation suggest an increase. As Calgary and Vancouver observed such decline in public transportation users, the gap between social and marginal costs become higher and so behavioural effects impact prominently. Furthermore, public transportation in these cities consequently realize a decrease in their income incurred from ticketing, assuming that pricing policies in the city remain constant, which makes completely sense because there would not be rationale to rise pricing policies whether the city experienced a drop of public transportation users. According to the financial theoretical model reported at chapter D.4.1, operating costs of public transportation in Calgary and Vancouver will remain stable with carsharing introduction, whereas the portion of deficit and income derived from ticketing are considerable affected by the emergence of carsharing services. Specifically, public transportation deficit grows, and so subsidies or public investment would be more requiring in this case because of carsharing introduction. Thus, coverage farebox coverage; F_{rr}, has been decreased by means of carsharing.

Additionally, when Calgary and Vancouver involved carsharing services, behavioural shift obtained an increase in private vehicles' use. As Downs-Thomson Paradox analysis, trade-off between individual and collective transportation also concludes that average costs of private vehicles grow because travel time increase, congestion and environmental in detrimental.

I. Calgary Farebox recovery rate and recommendations

Calgary was characterized by a farebox recovery rate by 50% in 2012[59], which means that the 50% of transit funding comes from ticket-sales revenues. Furthermore, as the number of public transportation users per day experienced a decline due to wider offer of alternative modes in the city such as carsharing, federal and government grants would be grosser unless Calgary' local subsidies policies recommends increases in their user fees, which could rebalance the recovery ratio target, even though public transportation experienced a downward tendency in demand due to carsharing services.

At the same time, Calgary price policy is based on flat rate network, which is directly translated to non-customized strategies dealing with a lesser equated price with the willingness to pay. For this reason, pricing policies in Calgary show up that they do not contribute to improve public funding in public transportation.

Otherwise, this report also concludes that an investment in public transportation in order to enforce an increase in their demand, the recovery rate significantly declines in short term because new offer take long term to settle the associated demand. Nevertheless, whether Calgary is customer-focused and based on efficient system that provides a variety of transportation choices to commute, public transportation capital projects in the city would be willing to enhance multimodal and integrated system among different modes of transport and to strengthen interchanges. If that was the case of Calgary, funding policies wishing to see a good steward for their latest technology to improve customer' experience and easy-to-use services will be initially requiring but could streamline public transportation drop on demand by combining means of mobility and understanding mobility as a service; both carsharing and public transportation.

II. Vancouver Farebox recovery rate and recommendations

Vancouver transport system holds a farebox recovery rate by 55% (TRANSLink, 2016). Although Vancouver case study behaves considerably similarly to Calgary when carsharing services are introduced into the city, it has further particularities as density of population and agglomeration are distinctive from the previous case.

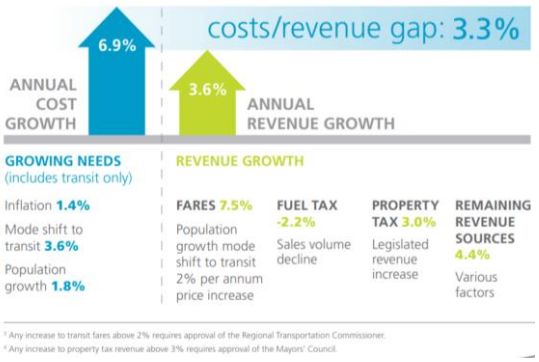
[59]City of Calgary, 13 January 2018, City of Calgary Transportation Approved 2015-2018 Action Plan.

Therefore, Vancouver transport network is based on zoning, but Calgary has flat rate network. Whereas Calgary puts evidence of non-contributing pricing system to commuters, Vancouver distribute the place by zoning, what embraces a first step to personalize tariff per distance. Although it is a good mechanism for close the financial gap between unitary and marginal costs in their mobility, it does not represent a profitable transit system as a whole.

According to the remarkable economical balanced MTR railway carriage undergone in Hong Kong, transportation should consider and understand the monetary value of urban density, which means that understanding the reality and the need to commute by public transportation in each city define possible government and transport providers strategies to close financial gap in the system. That is to say, Vancouver would also fight against their under-investment worsening because of shared mobility' emergence, but public transportation could also play role as businesses integrator whose Hong Kong took advantage.

Furthermore, public transportation in Vancouver and its high density of commuters all across the whole city put forward the momentum to develop vertical businesses integrated within transport network pods. In other words, mobility places where travellers visit upon their departure could include retail and other small businesses in order to help public transportation to recover percentage of their fare revenues. This income could be invested in pursuance of closing the deficit gap, although public transportation users have experienced a decline with carsharing.

Figure 40 Cost-revenues financial gap in Vancouver' transportation system



Source 40 Year-End Financial and Performance Report, TRANSLINK

F.1.2. French cities and territories study cases

French cities report another behavioural shift resulted by the introduction of carsharing. These cities experienced an increase of walking, bicycle and public transportation in broadly comparable. Furthermore, the emergence of carsharing all across France induces an increase of public transportation demand. In other words, as the number of users of public transportation per day grows, both average and marginal costs of this mode diminish.

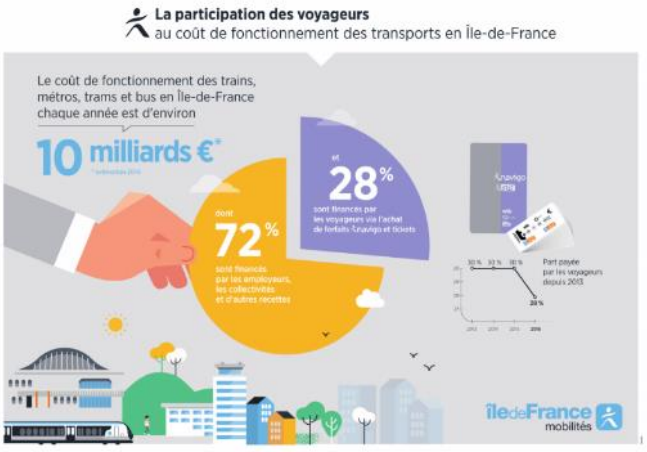
As this report learned in theoretical financial mode of public transportation, this transport mode holds an inherent deficit that requires subsidies. Otherwise, public transportation exploitation costs count with an income from ticketing, which will experience an increase because of public transportation demand' growth. All these insights are possible by assuming that pricing policies remained constant. All in all, coverage rate would increase in those cases and hence the need of public investment and taxes to cover public transportation is not such prominent with shared mobility implementation.

Conclusively, a decrease of private vehicles is shown by implementing carsharing in France so that average costs of private vehicle suffer a decline.

I. Ile de France Farebox recovery rate and recommendations

As Ile de France, in Paris realized a farebox recovery rate by 28%, and revenues resulted from ticket-sales in the region funds part of public transportation cost operation. The rest of operating costs to keep collective commutes, by 72%; subsidize transit development.

Figure 41 Operating costs of public transportation in Ile de France, Paris



Source 41 Ile de France mobilités. Le financement des transports publics

Unlike other analysed cities, Ile de France exhibits an increase of public transportation demand because of Mobizen carsharing service adoption all across the city. Nevertheless, Autolib carshare shows different behavioural shit on public transit demand. Among those users who have been driven to use carshare and public transportation complementary; Mobizen, the under-investment gap of public transportation fosters a reduction, that is, without changing pricing strategies and considering an increase on demand feasible respond according to the existent infrastructure in the city.

Additionally, Parisian transport system is based on zoning and ticketing policies in adequacy with travelled distance so pricing for travel in public transportation is closer to equilibrium with social marginal costs. This feature, added to the above, contributes to minimize subsidies percentage beyond operating costs in public transportation. Not to mention that Mobizen suggests to be distributed strategically complementary with public transportation stations to induct additional demand rather than be in detrimental of its use as results of Autolib.

Otherwise, Autolib would experience a similar tendency to North American cities study case detailed at chapter F.1.1 as the result in public transit demand share behaves in the same way.

II. Out of Ile de France - Farebox recovery rate and recommendations

As discussed at chapter E.3.2.II, interurban areas through which citizens daily access to the metropolitan areas are the most densely congested displacements. Nevertheless, the strategical deposition of carshare services to smart interconnect interurban with urban areas results favourably to public transportation usage. In other words, although interurban areas seem the most challenging geographical location to foster sustainability and fight against congestion, travel time losses and air pollution derived from bottle necks, car sharing disruptive business models provide combined transport modes; public transit and car share to easily access to metropolitan city.

Furthermore, subsidies and public transportation funding incurred from public fares are subjected to a downward incline because of intelligent interconnectivity with carsharing.

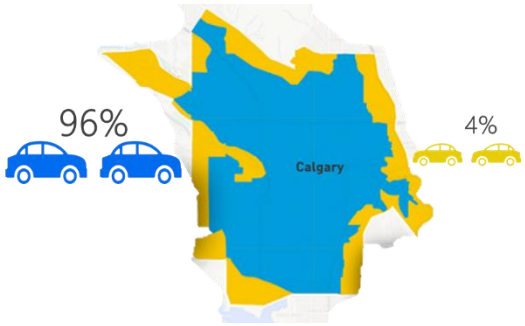
In addition, sum to the fact that interurban areas are another debate open to further discuss, some particular carsharing services such as SocialCar (i.e. peer-to-peer) seem more appropriate to those mobility commuters' requirements as they share their personal vehicles growing their occupancy of passengers per each one to access to the metropolitan area. This could respond to the challenge that usually carsharing services and fleet spread face to be present among both urban and suburban areas. That is to say that many times, as Autolib and Mobizen experience, carsharing operators that own a fleet are not well-deployed in suburban areas as the distance to access to one car share usually is excessively long to adopt this mode of transportation.

Figure 42 Ile de France: metropolitan and interurban area carshare distribution (blue-Autolib versus green-Mobizen)

Source 42 Enquête sur l'impact d'un service d'autopartage en trace directe (le cas Autolib' et le cas Mobizen)

Plus, another example of carsharing that had reduced their operating scope because of interurban lack of demanding share is Car2Go operator in Calgary, being centralized to metropolitan area and downtown side.

Figure 43 Calgary: Downtown and suburban area carshare demand distribution (Car2Go)



Source 43 City of Calgary, 2015, CBC News: Car2Go car sharing service cuts Calgary service area. Cuts service to members in outskirts to address shortage downtown

F.1.3. Multi-modal transport system case study

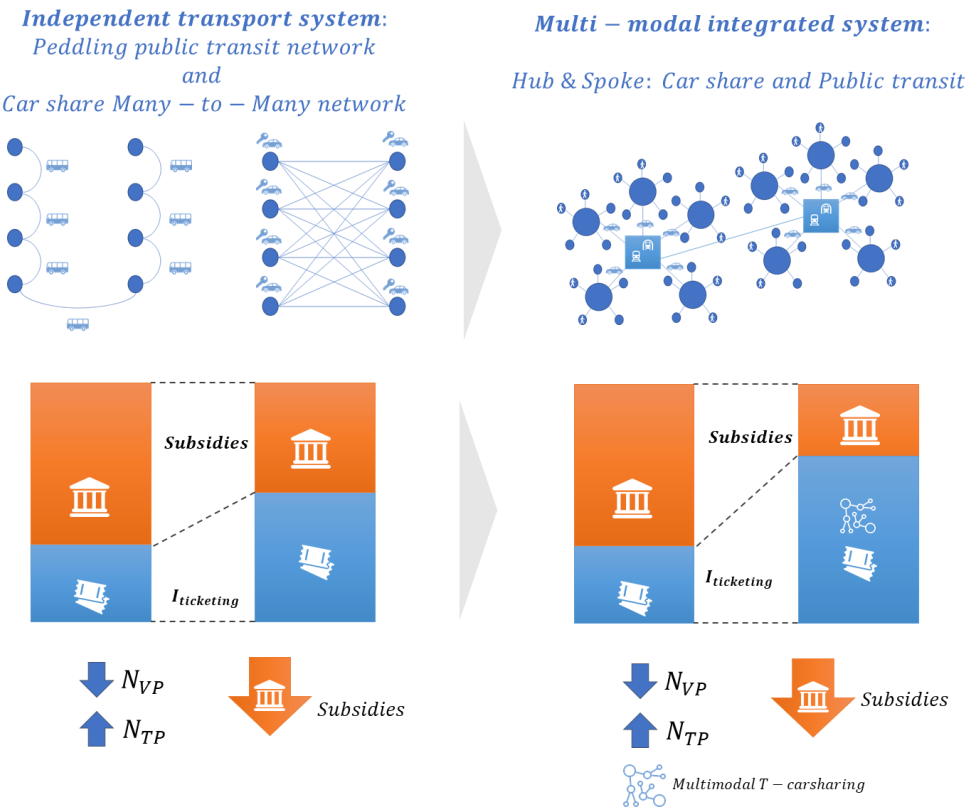
As reported in France case study, multimodal transport system and transfer easiness between different modes of transportation inducts an increase of public transportation demand. Furthermore, although these real cases show a growth in public transportation, it presents a more prominent increase on its demand with the disposal of integrated transport system, which provides accessibility, connectivity and reduction of transfer time costs.

The importance of multimodal goes further interconnections, it additionally persuades commuters to adopt sustainable modes of mobility even more compared with the precedent inexistence of carsharing.

This solution not only increases the revenues derived from ticketing as a result of an upward tendency in public transportation demand, it also improves exploitation costs by integrated and multimodal pricing policies based on a more accurate tariff according to use and demand. Thus, multimodal transportation between carsharing and public transportation is the opportunity to modernise and update traditional collective transport with the adaptation to innovative modes such as carsharing services.

Not to mention, this insight agrees to the fact that carsharing and public transportation multimodality is also reshaping the transport network planning towards Hub & Spoke distribution.

Figure 44 Farebox recovery rate variation from Many-to-many carshare system to Hub & Spoke complementary to public transit system



Source 44 Author's own

G. CONCLUSIONS

Although the implementation of carsharing into the whole transport system behave differently in each city, this report strongly concludes different findings to be highlighted.

These new services - carsharing – provide some notorious advantages externalized from private vehicle such as comfort and flexibility as well as they rely on notable extra advantages compared to vehicle ownership; pay-per-use policies, eco-friendly, ubiquitous and optimisation of travel time. No to mention, shared mobility services are transforming the mindset of multimodal convenience. Thus, **carsharing disrupts how commuters are currently embracing single-occupancy vehicles** and puts forward a significant alteration of decision-making variables in our transport modal choice.

As a matter of fact, **carsharing emerges in the new mobility ecosystem that set to provide a viable alternative to car ownership** delivering eco-friendly options, not only by means of electric carsharing, but also by shifting more users to combine public transportation with carsharing in their daily trips, conforming a more sustainable mobility usage.

Multimodal transport system between public transportation and carsharing through integrated ticketing system **encourages more commuters to leave their private vehicles onto public transportation and sustainable mobility modes**. Another feature that affects to the behaviour of modal choice between collective and individual means of transportation is the optimization of carsharing pods' location interconnected with public transportation stations, and hence transitioning into Hub & Spoke network that enhances Mobility as a Service. Furthermore, **this new paradigm puts forward more travellers using a combination of public and private transit options** and some of the necessary motivators or drivers for that have been convenient for them; price integration and travel time optimisations.

Even more, the typical profile of carsharing member increase modal shift impacts prominently with an increase in the frequency of use. In other words, **multimodal transport use also grows with the amount of membership in carsharing.** At the same time, among the different mobility patterns and categories of commuters, carsharing alters some of the envisions that users embrace in their transport modal

choice; faithful customer to private vehicle might not be carsharing members in short time because of their priorities, but in long term in where land use and multimodal transport options would have evolved, carsharing could be suitable for them. Apart from that, closeness, shortest and sustainability are some of prior considerations for potential carsharing membership up until now.

Even though public transportation requires public subsidies, that cover only a portion of total operating costs by inherent nature, **carsharing implementation mainly suggests an improvement of these nonuser fee revenues by means of behavioural modal shift**. Furthermore, whether carsharing drives a decline in public transportation usage, the farebox recovery rate also decreases. Whereas, if carsharing leads to an increase in public transportation subscription, fare revenues consequently grow so that it closes its deficit gap. At the same time, cities in which shared mobility maturity model is more mature, the implementation of carsharing delivers improvements to public transportation public funding, whereas in cities where shared mobility maturity model is non-mature the consequent effect behaves inversely.

Additionally, more personalized and pay per use pricing policies is translated into an increase of fare recovery rate. Among different carsharing case studies, the more transit system based on zoning and pay per distance, the lesser financial gap public transportation is suffering.

An intermodal and PPP models in transportation are the opportunity for traditional public transportation models to anticipate to disruptive and innovative private means of mobility. In other words, **federal and state governments as well as public transport operators should take advantage of the changeable momentum of transportation and digital era to build cohesive and collaborative alliances with private emerging mobilities such as carsharing**. The flexibility, ubiquitous, customized pricing are some of the advantages that emerging transport modes provide to commuters, so public transportation operators should admit their potential to strengthen their level of service and exploitation by means of sharing multimodality with private companies. As this report observed, public transportation is stronger with PPP mindset rather than working vertically as it has done until the moment.

Following the previous statements, **carsharing becomes a driver to new PPP collaborations worldwide** as it does not represent an independent means of mobility,

it caters public and private sides to be implemented and thus **represents a catalyst for new PPP collaborative financial models**.

All in all, carsharing should not be understand as competitive means of mobility for public transportation. Have Uber and Lyft been perceived as competitors for taxi drivers? Yes, this is not open to debate, but the fact that we are moving towards a digitalization where technology is permeating everything, do we expect to remain always in the traditional transit models? I would say it its optimistic as well as unrealistic. **Technology and ubiquitous connectivity are changing everything and even transportation**. For this reason, public transportation has the opportunity to anticipate new emerging trends and combine collaborative models – as they could be better improved- or remain reluctant to independent and transit silos. A clear example of it, although it has been proved that many cities are altered by carsharing implementation, it is not always in detrimental way as many times peak carsharing ridership happens outside public transportation operating hours.

In Smart Cities, collaborative models between public and private sides are commonly built because of them and their competences together can seek for the citizens' welfare. Furthermore, in **Mobility as a Service does the same apply although some concerns from stakeholders seem prominent and should be broken for commuters' convenience as well as for the improvement of public transportation' investment.**

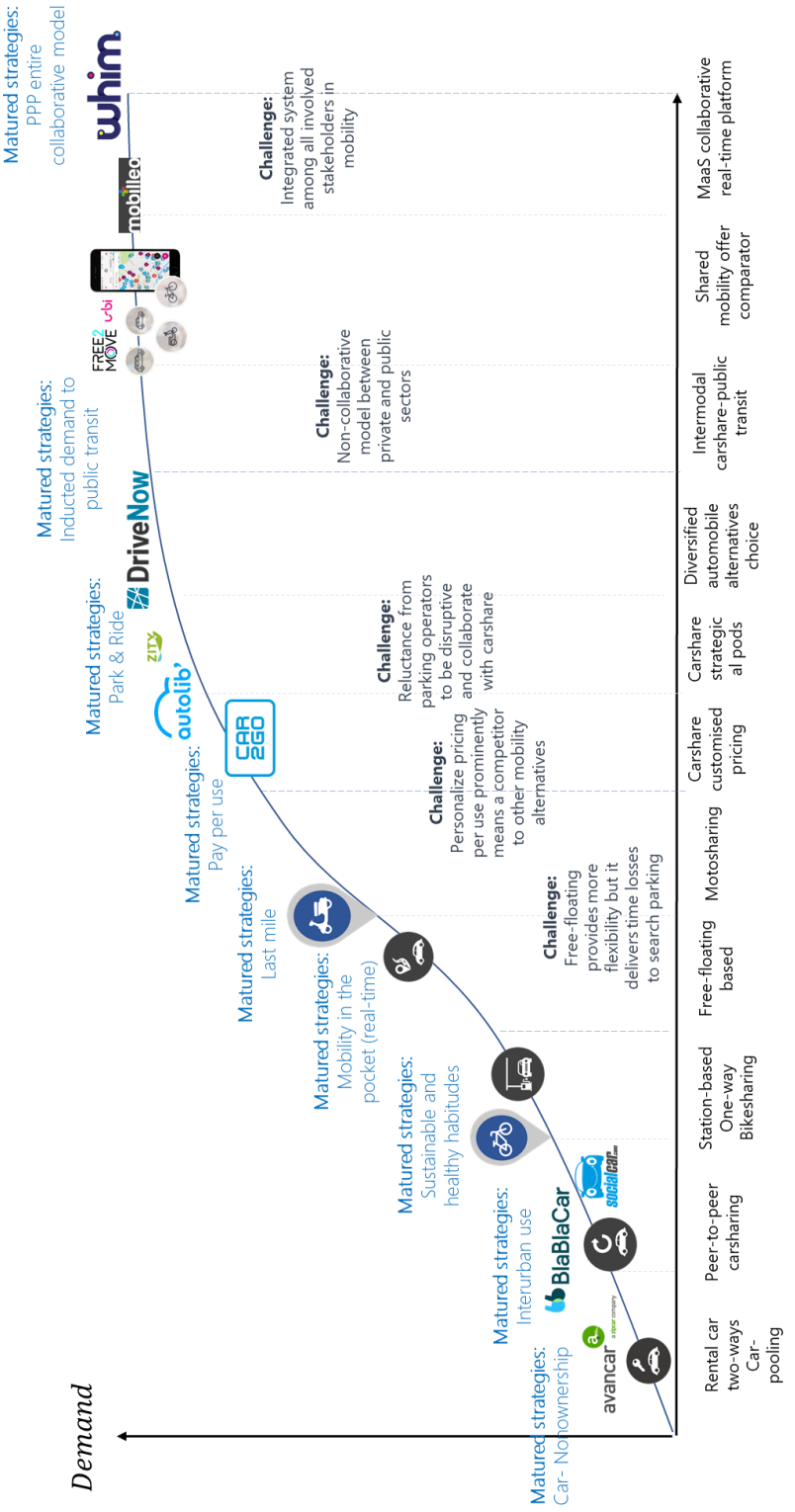
H. FUTURE LINES

H.1. Shared mobility maturity model effects on subsidies

Shared mobility services have taken off in cities around the world. But they are merely a sign of even bigger things to come and are now beginning to hit the subsidising traditional model of public transportation. Cities at the forefront of these disruptive shared mobility services that have been disparately introduced in many cities as each one responds to a variety of challenges and particular barriers. Although car share introduction behaves differently to public transportation modal shift, and thus to their funding model, other considerations should contribute towards financing decision-making process as mobility is a public right indispensable to undergone within any daily routine. Not to mention that some cities have bet for offering a greener alternative to car sharing initiatives also based on shared economy; bike sharing either moto sharing. How does the woven through these disparate shared mobility services shift transport scheme in cities? Bike sharing scheme goes along a change of mindset, and it furthermore changes mobility patterns, reason why this future line of research wonders of whether the maturity model of shared mobility along different cities and territories disturb the behavioural shifting findings reported through this research; modal choice, multi-modality and public investment.

Furthermore, the contours of each nation's transport system set boundaries on the role that local government can play by means of the maturity level where they take side. Nevertheless, if municipalities deploy all the mechanisms included in the maturity model to their fullest effect, its transport system do not guarantee the greatest subsiding model by their own. That is to say, shared mobility maturity model does not experience advancements without the proactivity and collaboration of private sector, playing an increasing role in the conception of Mobility as a Service paradigm. Today, the pushback in favour of privacy has been strong among carsharing services worldwide, but similar advocacy efforts are not always present in deploying integrated and multi-model cohesive system for the sake of commuters.

Figure 45 Carshare maturity model



Source 45 Auhtor's own. Data: Multiple sources

To help city leaders structure their transportation maturity grow, they and public transportation should understand the convenience of taking the plunge to search for Public-Private Partnerships that would ensure the deployment of qualified shared mobility. At the same time, another barrier to date has been the reluctance of private sector to liaise with municipalities in order to pursue the cohesive, transversal and integrated platform reached at the final step of the maturity model; Figure 45. This latest matured model, for instance, has been implemented in Helsinki by means of Whim app[60], which is an open data platform that integrates all the gathered information from the whole transport ecosystem in the city; both public and private, to provide qualified real-time knowledge to all commuters from any location.

Even if car share resulted in detrimental of public transportation in some cities, an integrated and multi-modal commuting system could conclude a favourable impact to public transit usage and thus to public subsidising model. For these studies cities, and in accordance to the maturity model developed, many strategies emerge to foster sustainability, pay-per-use conveniences, park & ride mechanisms, building a more Hub & Spoke transport distribution and also varying the urban distribution of goods by strategies such as last mile. But it is not considerable shifting the subsiding model until reaching PPP collaborations, through which the creation of common efforts by public-private sectors emerges seeking for the integration of shared mobility and other alternatives itinerary into a unique *Mobility-as-Service* platform. To this point, carshare - ubiquitous services and transformed connectivity - delivers a complementary use of mobility modes, combining them for the convenience of travellers. Doing this; bringing public and private sectors to their sense as well as making urban parking operators see the convenience to collaborate with disrupting and innovative forms of mobility, can completely change the understanding of mobility and the way people is getting around.

[60] https://whimapp.com/

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